To William Fisher
In memory of his
Uncle John Reed
July 15 - 1840

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SIR ISAAC NEWTON,

London; Published by Hodgson & Co. 10, Newgate Street.

THE

ARTISAN;

OR,

MECHANIC'S INSTRUCTOR:

CONTAINING

A POPULAR, COMPREHENSIVE, AND SYSTEMATIC VIEW OF THE FOLLOWING SCIENCES:

GEOMETRY,	ASTRONOMY,
MECHANICS,	ARCHITECTURE,
HYDRODYNAMICS,	PERSPECTIVE,
PNEUMATICS,	ELECTRICITY,
OPTICS,	MAGNETISM,
CHEMISTRY,	ALGEBRA.

ALSO

Biographical Notices of eminent Scientific Men,

ENRICHED BY PORTRAITS:

WITH MANY INTERESTING AND VALUABLE ARTICLES

RELATING TO

THE MECHANICAL AND USEFUL ARTS.

THE WHOLE INTENDED AS A

COMPANION TO THE INSTITUTES.

VOL. I.

LONDON:
PRINTED FOR WILLIAM COLE,
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1825.

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PREFACE.

NOTHING tends so much to the successful cultivation of scientific knowledge, as forming clear and accurate ideas of the Elements, or first principles, of those sciences which form the basis of all *physical* knowledge. Convinced of the truth of this observation, and of the value of scientific knowledge to the Artisans and Mechanics of this commercial and manufacturing country, the Editor of the following work has endeavoured to render the various subjects contained in it as plain and as easily understood as the nature of them would permit.

In pure Geometry, it is scarcely possible to abridge the steps of a demonstration, without rendering the truth of the proposition less apparent; it has therefore been deemed more advantageous to the Geometrical student, to present him with the Propositions of Euclid's Elements, without attempting any abridgement or alteration of them. He will, however, find many observations and useful remarks, on a number of the propositions, that are not to be found in the common editions of the Elements.

The science of Mechanics, though more intricate and complex than Geometry, may nevertheless be very much simplified in many of its most useful and practical branches, by explaining the laws and principles upon which they rest, in *common language,* instead of expressing them in mathematical and *algebraical symbols.* This has been particularly attended to, in delivering the general doctrines of this science in the following work, as well as in treating of the power and effects of particular machines.

The same rule has been observed in treating of Hydrodynamics, Pneumatics, Optics, and Astronomy, though they are strictly mixed mathematical sciences, and have hitherto been treated in the most abstract and mathematical manner, even in works pretending to be purely elementary.

The science of Chemistry is also rendered as simple and amusing as it is possible to make it; and the most accurate and modern improvements which have been introduced into that science have been noticed.

To render the work useful and amusing, not only to the scientific student, but to the general reader, an extensive miscellaneous department has been added, including memoirs of the lives of men who have distinguished themselves, either by the improvements they have made in the Sciences, or the discoveries they have made in the Arts. Another important feature of this department of the work is, a comprehensive and popular view of the beautiful and elegant science of Architecture, illustrated by neatly engraved specimens of the various orders of building, both ancient and modern.

The other subjects introduced into the Miscellaneous part of the work, are perhaps as numerous as in some other works, which are appropriated solely to subjects of this nature. And, upon examination, they will be found not only interesting and useful at the *present* time, but to be of such a nature, as to render them equally useful at any *future* period.

The mathematical and philosophical questions contained in the work may, perhaps, be considered by some as of too abstruse and intricate a nature to be generally understood; but the reason for devoting a small portion of the work to subjects of this kind, was to render it interesting, and, if possible, valuable to the mathematician, and the philosopher, as well as the tradesman and the mechanic.

The *Copper-plate* portraits which are given along with the work, are of the very first order in point of execution; the same may be said of the numerous *Wood* engravings interspersed through it. But a careful perusal of the whole, and a comparison with other works that treat of the same subjects, will afford the best *criteria,* for determining both the *comparative* and *real* value of the work now offered to the public.

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The Artisan;

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A COMPANION TO THE INSTITUTES.

INTRODUCTION.

THE value of scientific knowledge is now so generally known and appreciated in this country, that any attempt to point out the advantages resulting from an acquaintance with it, would be quite superfluous. It must, however, be admitted, that the *value* of this species of knowledge is more generally understood than the *principles* upon which it is founded. The effects produced by it are seen and acknowledged by all; but comparatively few are acquainted with the mode of producing them. Every one has seen and must admire both the structure and powerful effects of the Steam-engine; but few are acquainted either with the scientific principles upon which its construction depends, or with the nature of the extraordinary fluid by which its surprising effects are produced. Being fully convinced of the truth of these observations, and of the great importance of scientific knowledge to every individual engaged in the cultivation of the Arts, the Conductors of the present Publication have resolved to devote the greater part of the work to the developement and explanation of the fundamental principles of those Sciences which form the basis of the Mechanical Arts. Particular care will, therefore, be taken to give a comprehensive and connected view of the most useful branches of Mathematics, Mechanics, Hydrostatics, Pneumatics, Optics, Astronomy, and Chemistry.

In treating of these sciences, the greatest pains will be taken to render them as plain and easily understood as their nature will admit;—and in order to render the work of permanent utility, not only to those who are beginning the study of these sciences, but to those who are already well acquainted with them, a regular and systematic arrangement of the various parts of each will be preserved, and no part omitted which can be considered of real value.

Mathematical knowledge being the foundation of all physical science, as well as most of the mechanical arts, has certainly the first claim to attentive observation; a portion of "Euclid's Elements" will therefore be given in each Number of the "ARTISAN," in a more simple and popular form than that celebrated work has ever yet assumed: for although we are perfectly aware that "there is no *Royal Road* to Geometry," yet we do think that many of the Propositions in that work may be made more intelligible to mathematical Students than they are, as they stand in the most popular editions of the Elements. It will, therefore, be the particular care of the Conductors of the "ARTISAN," to make this part of the work as easily understood as possible, knowing that little progress can be made in any of the physical sciences without possessing a tolerable share of mathematical knowledge. This is a fact so well known to those who have made those sciences their particular study, that no arguments can be employed to give additional weight to it. And though it may be impossible to give an adequate idea of the usefulness of mathematical knowledge to those who are wholly unacquainted with it, yet it may afford some satisfaction to those who are about to commence the study to observe, that mathematical knowledge supplies most of the means by which the business of society is carried on, and its comfort secured. To mathematical principles the skilful Architect necessarily resorts for the means of contriving and executing his plans; and to them every building, from the cottage to the palace, owes its existence. By mathematical knowledge the mariner shapes his course through the wide and pathless ocean, the intrepid soldier plans his operations for the protection of his country, the skilful miner contrives his subterraneous excavations, and procures for our use most of the substances employed in the arts of civilized life.

Having here stated, in general terms, some of the uses of mathematical science, it is unnecessary to make any observations on the other sciences to be introduced in the present publication, because the utility of these are much more apparent to the generality of mankind, than the science upon which they immediately depend. But though this be the case, the sciences themselves are necessarily as little known as the elementary branches of mathematics. It will, therefore, be the study of the Conductors of the "ARTISAN" to present their readers with a regular and comprehensive view of the various branches of Natural Philosophy, as far as they are known at the present day. And to render their work of general interest, part of each Number will be devoted to giving an account of any discovery or improvement that may be made in the Arts; with biographical notices of men who have contributed to the advancement either of the Arts or Sciences.

The Editors will therefore receive with gratitude short and authentic communications relative to every species of useful knowledge; but they have resolved to exclude every thing of a speculative nature, and to confine their work entirely to the promulgation of facts founded on experiment and observation. By thus selecting and condensing their materials, and by endeavouring to give a popular form to the various subjects that come under their notice, the Conductors of the "ARTISAN" trust that they may, in some degree, advance the interest of science, by promoting its general diffusion, at a time when there is so much anxiety shown by every class of the community to acquire a knowledge of the accurate sciences.

The Editors also trust that the plan here adopted, of giving a clear and connected view of each of the Sciences contained in the present Number, will be considered the most effectual mode of aiding the laudable exertions now making by the operative Mechanics of this Country, to acquire a knowledge of the principles upon which their respective arts depend. They are, therefore, not without hopes that their exertions may successfully contribute to the diffusion of scientific knowledge, as well as to the advancement of the useful Arts.

BIOGRAPHICAL MEMOIR

OF

SIR ISAAC NEWTON.

Sir Isaac Newton, one of the greatest mathematicians and philosophers that ever lived, was born in Lincolnshire, in 1642. Having made some proficiency in the classics, &c. at the grammar school at Grantham, he (being an only child) was taken home by his mother (who was a widow) to be her companion, and to learn the management of his paternal estate: but the love of books and study occasioned his farming concerns to be neglected. In 1660 he was sent to Trinity College, Cambridge: here he began with the study of Euclid, but the propositions of that book being too easy to arrest his attention long, he passed rapidly on to the Analysis of Des Cartes, Kepler's Optics, &c. making occasional improvements on his author, and entering his observations, &c. on the margin. His genius and attention soon attracted the favourable notice of Dr. Barrow, at that time one of the most eminent mathematicians in England, who soon became his steady patron and friend. In 1664 he took his degree of B.A. and employed himself in speculations and experiments on the nature of light and colours, grinding and polishing optic glasses, and opening the way for his new method of fluxions and infinite series. The next year, the plague which raged at Cambridge obliged him to retire into the country; here he laid the foundation of his universal system of gravitation, the first hint of which he received from seeing an apple fall from a tree; and subsequent reasoning induced him to conclude, that the same force which brought down the apple might possibly extend to the moon, and retain her in her orbit. He afterwards extended the doctrine to all the bodies which compose the solar system, and demonstrated the same in the most evident manner, confirming the laws which Kepler had discovered, by a laborious train of observation and reasoning; namely, that "the planets move in elliptical orbits," that "they describe equal areas in equal times;" and that the squares of their periodic times are as the cubes of their distances. Every part of natural philosophy not only received improvement by his inimitable touch, but became a new science under his hands: his system of gravitation, as we have observed, confirmed the discoveries of Kepler, explained the immutable laws of nature, changed the system of Copernicus from a probable hypothesis to a plain and demonstrated truth, and effectually overturned the vortices and other imaginary machinery of Des Cartes, with all the improbable epicycles, deferents, and clumsy apparatus, with which the ancients and some of the moderns had encumbered the universe. In fact, his *Philosophiæ Naturalis Principia Mathematica* contains an entirely new system of philosophy, built on the solid basis of experiment and observation, and demonstrated by the most sublime Geometry; and his treatises and papers on optics supply a new theory of light and colours. The invention of the reflecting telescope, which is due to Mr. James Gregory, would in all probability have been lost, had not Newton interposed, and by his great improvements brought it forward into public notice

In 1667, Newton was chosen fellow of his College, and took his degree of M.A. Two years after, his friend Dr. Barrow resigned to him the mathematical chair; he became a member of parliament in 1688; and through the interest of Mr. Montagu, Chancellor of the Exchequer, who had been educated with him at Trinity College, our author obtained in 1696 the appointment of Warden, and three years after that of Master, of the Mint: he was elected in 1699 member of the Royal Academy of Sciences at Paris; and in 1703 President of the Royal Society, a situation which he filled during the remainder of his life, with no less honour to himself than benefit to the interests of science.

In 1705, in consideration of his superior merit, Queen Anne conferred on him the honour of knighthood: he died on March 20th, 1727, in the 85th year of his age. His works, collected in 5 volumes, 4to. with a valuable Commentary by Dr. Horsley, were published in 1784.

GEOMETRY.

GEOMETRY is that branch of the Mathematics which treats of figure and extension; and is divided into *Plane* and *Solid*.*

Plane Geometry being the foundation, not only of solid Geometry, but of most of the other branches of the Mathematics, it naturally falls to be considered before any of the other branches;—and as *Euclid's Elements* is generally allowed to be the best system of Geometry that has yet made its appearance in the world, we shall adopt that celebrated work as our text-book in treating of Geometry, in this and the succeeding Numbers of the ARTISAN.

In attempting to illustrate, or explain, the following definitions and propositions, we are perfectly aware that many of our expressions and illustrations will be objected to by the speculative and rigid mathematician; but, as we have already stated elsewhere, our object is simplicity; and to convey a knowledge of the sciences to those who are wholly unacquainted with them.

DEFINITIONS.†

1. A Mathematical *point* is that which hath no parts nor magnitude.
2. A line is length without breadth.
3. The extremities of a line are points.

It is evident that there is nothing in nature agreeing with, or corresponding to, a point or a line taken in the sense of the first and second definition; but still they may be comprehended by the mind, for they may be conceived to mark the position where a real point or a line may be formed. In the case of a real distance between two places, which is certainly a line, no enquiry is ever made about the breadth of that distance.

4. A straight line joining any two points upon a plane, or surface, lies wholly on that surface.
5. A superficies is a space which has only length and breadth, or it is a surface, without thickness.

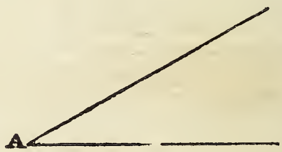
In speaking of the superficies, or surface, of a table, a wall, or a field, the thickness is laid out of the question.

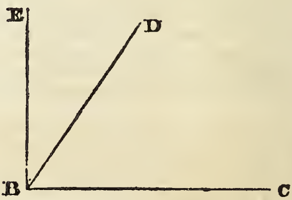
6. The extremities or boundaries of a superficies are lines, which may be either straight or curved.—A circle is bounded only by one line.

7. A plane superficies is that in which any two points being taken, the straight line joining them lies wholly in that superficies.

This will perhaps be better understood by considering the nature of a *curved* superficies; as the surface of a globe, for example. If two points be taken on its surface, the straight line that joins them does not lie wholly in that superficies, and therefore, the surface of a globe is not a *plane* superficies.

9. A *plane* rectilineal angle is the inclination of two straight lines to each other, meeting in a point. Or, it is the opening, or diverging, of two straight lines from a point.





If there be only one angle at a point, as at A, then it may be expressed by one letter placed at the angular point. But when several angles are formed at the same point, it is necessary to employ *three* letters, to express any one of these angles; and the letter which is at the angular point is put between the other two letters.* Thus the angles at the point B, which is formed by the lines B C and B D, is named the angle C B D or D B C; and the angle formed by the lines B D and B E, is named the angle D B E or E B D.

When two angles are separated from each other only by a straight line, as the angles C B D and D B E, they are called adjacent angles.

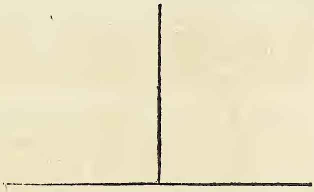
10. When a straight line standing on another straight line makes the adjacent angles equal to one another, each of these angles is called a *right* angle; and the

* The word Geometry is formed from two Greek words; and literally signifies to measure the earth.

† Though some of Euclid's definitions are omitted, as being unnecessary, yet those which are introduced here are numbered as in Dr. Simpson's Euclid, which is the one we intend to use in the present work.

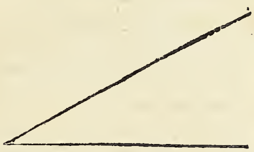
* A straight line is usually expressed by placing a letter at each end of it.

line which stands on the other is called a perpendicular to it.

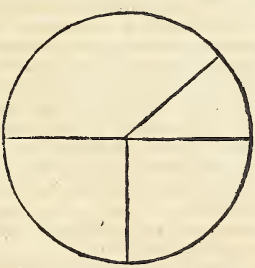


11. An obtuse angle is that which is greater than a right angle.

12. An acute angle is that which is less than a right angle.



13. A circle is a plane figure contained by one line, which is called the circumference; and is such, that all straight lines drawn from the centre to the circumference are equal to one another.*



14. A diameter of a circle is a straight line drawn through the centre, and terminated both ways by the circumference.

15. A semi-circle is that part of a circle contained between the diameter and circumference.

16. A segment of a circle is that part of the circle contained between part of the circumference, and a straight line which cuts off that part of the circumference.

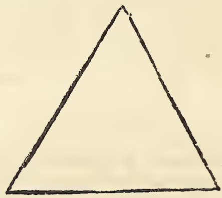
17. Rectilineal figures are those which are contained by straight lines.

18. Trilateral figures, or triangles, are contained by three straight lines, ———.

19. Quadrilateral figures by four straight lines.

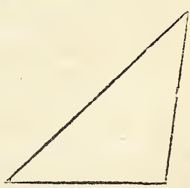
20. Multilateral figures, or polygons, by more than four straight lines.

21. An equilateral triangle is that which has *three equal* sides.

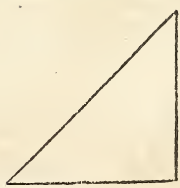


22. An isosceles triangle, is that which has *two* sides equal.

23. A scalene triangle, is that which has three unequal sides.



24. A right angled triangle, is that which has a *right angle* in it.



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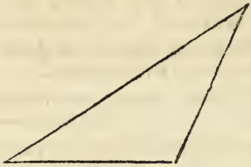
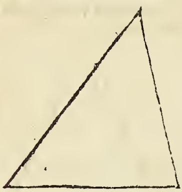
* A plane surface included by one or more lin is called a mathematical figure, as a triangle, square, &c.

25. An obtuse angled triangle, is that which has an obtuse angle in it.



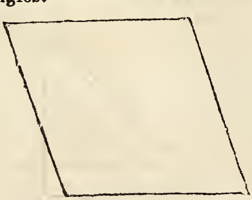
26. An acute angled triangle, is that which has three angles acute.



27. Of four-sided figures,—a square is that which has all its sides equal, and all its angles right angles.

28. An oblong, or rectangle, is that which has all its angles right angles, but not all its sides equal.

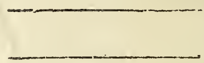
29. A rhombus, is that which has all its sides equal, but none of its angles are right angles.



30. A rhomboid, is that which has its opposite sides equal to one another, but none of its angles are right angles

All other *four*-sided figures besides these are called trapeziums.

Parallel straight lines, are such as are in the same plane, and though produced ever so far both ways, do not meet.



MECHANICS.

Mechanics, is a mixed mathematical science, which treats of the nature, production, and change of motion.

When bodies are free to obey the impulses communicated to them, that branch of Mechanics which treats of their motion is called *Dynamics*.

Dynamics is the most elementary branch of the doctrine of motion, and is also the most general in its principles.

Previous to entering upon the explanation of the general laws of motion, or what is termed the composition and resolution of *forces*, it will be necessary to state a few of the general properties of matter, as well as to explain a few terms which frequently occur in treating of philosophical subjects.

Matter is a substance, the object of our senses, in which are always united the following properties: extension, figure, solidity, mobility, divisibility, gravity, and inactivity.

Extension may be considered in three points of view: 1st. As simply denoting the part of space which lies between two points, in which case it is called *distance*. 2d. As implying both length and breadth, when it is denominated *surface* or *area*. 3d. As comprising three dimensions, length, breadth, and thickness; in which case it may be called *bulk*, *solidity*, or *content*. When considered as a property of matter, it is used in the last of these senses.

Figure, is the boundary of extension: for all bodies are included by one or more boundaries, and consequently possess figure; they have also the capacity of receiving an indefinite variety of figures. Some bodies receive new figures with difficulty, but maintain them easily; such are the bodies usually called *solid*. Others receive any figure easily, but cannot maintain it without the assistance of other bodies; fluid bodies are of this kind.

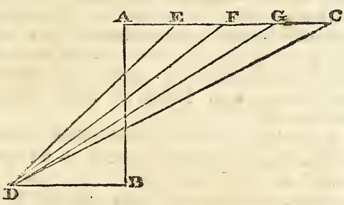
Many bodies have figures that are peculiar to them in their natural state. This is the case not only with plants and animals, but with certain mineral productions called crystals, which are usually bounded by plane surfaces.

Mobility, or a capacity of being moved from one place to another, is a quality found to belong to all bodies upon which we can make suitable experiments; hence we conclude that it belongs to all bodies.

Divisibility signifies a capacity of being separated into parts.

That matter is thus divisible, our daily experience convinces us. How far the division can actually be carried is not so easily ascertained: we are, however, certain that many bodies can be divided into very minute parts. Of this we have examples in the gilding of silver wire, in the propagation of odours, and in the colours produced by chemical solutions, &c. These, and other considerations, lead us to conclude that the division of matter is carried to a degree of minuteness far exceeding the bounds of our comprehension; and it seems not unreasonable to suppose, that this capability of division is without limit, or as it is usually expressed, *ad infinitum*.

That any portion of extension is divisible into parts which become less and less without end, may easily be perceived, by a moment's consideration of the following figure.



Suppose the line A B is to be divided into as minute parts as possible. It will soon be perceived, that if the line A C be extended indefinitely, and that an unlimited number of points, as E, F, G, &c. may be taken in it; and if straight lines be drawn from these points to the point D, the line A B will be divided into an indefinite number of parts. Hence it appears that the division of the line A B may be continued *ad infinitum*.

Gravity is the tendency which all bodies have to the centre of the earth.

That all bodies have this tendency experience convinces us; for we see that when a body is supported, its pressure is exerted in that direction; and when every impediment is removed, it always *descends* in that direction.

The *weight* of a body is its tendency to the earth, compared with the like tendency of some other body, which is considered as a standard. The weight of a given body may, therefore, be employed to measure the weights of all other bodies.

From these definitions it appears, that *gravity* must be distinguished from *weight;* for the force of gravity is the same in all bodies; that is, all bodies have an equal tendency to the earth, and would fall at the same rate to the ground were the resistance of the air removed; but it is well known that the weight of all bodies are not the same.

As gravity is a property belonging to every particle of matter, however minute, the *weight* of a body is the sum of the gravities of all its particles; or it is the product of all its particles, multiplied by a single particle. *Inactivity* may be considered in two lights: 1st. As an *inability* in matter to change its state, whether it be at rest or in motion. 2d. As that quality by which it *resists* any such change. In this latter sense it is usually called the *force of inactivity*, the inertia, or the *vis inertiæ*.

That a body *resists* any change in its state of rest, or uniform rectilinear motion, is known from constant experience. We cannot move the least particle of matter without some exertion; nor can we destroy any motion without perceiving some resistance.*

Thus we see, in general, that *inertia* is a property inherent in all bodies with which we are acquainted; different indeed in different cases, but existing, in a greater or less degree, in all.

These properties, which are always found to exist together in the same substance, have sometimes been said to be essential to matter. Whether they are or are not *necessarily* united in the same substance, it is impossible to decide, nor does it concern us to inquire. Our business is not to find out what might have been the constitution of nature, but to examine what it is in fact, and to account for the phenomena, or appearances, which fall under our observation, from those properties of

* This resistance is quite distinct from, and independent of, *gravity;* because it is perceived where gravity produces no effect: as when a wheel is turned round its axis, or a body moved along a horizontal plane.

matter which we know by experience that it possesses.

The *density* of a body is measured by the quantity of matter it contains in a given bulk; and the quantity of matter in any body is always proportional to its weight. That is, a body which is double the weight of another body contains double the quantity of matter.

The *specific gravity* of a body is the weight of a given *bulk* of it, compared with an *equal bulk* of another body, which is assumed as a standard of comparison.—Water has been generally assumed as this standard; hence it is said that the specific gravity of gold is 19, which signifies that any given bulk of gold is as many times the weight of an equal bulk of water.

By *motion* we understand the act of a body constantly changing its place; and is generally considered of two kinds, *absolute* and *relative*.

A body is said to be in *absolute motion*, when it is actually transferred from one place to another; and to be *relatively* in *motion*, when its situation is changing with respect to the bodies around it.

These two kinds of motion often coincide; as for example, when a person walks from any given place to another, he changes his place both absolutely and relatively with respect to the first place; but if another person walks by his *side* all the time, he has no relative motion with respect to him.

When a body passes over equal parts of space, in equal portions of time, its motion is said to be *uniform*. When its motion continually increases, it is said to be *accelerated;* and when it continually decreases, to be *retarded*. If it increases or decreases uniformly, it is said to be equally *accelerated*, or retarded.

When a body falls from any considerable height, its motion is uniformly accelerated, or its velocity increases proportionally to the time; but if a body be projected directly upwards, its motion will be uniformly retarded, or its velocity will decrease proportionally to the time it has been in motion.

In measuring the velocity of bodies, it is necessary to take a certain portion of time as the unit, or standard, to which all other portions of time may be referred. The unit generally employed for this purpose is one *second*.

The space passed over in any time, by a body moving with a uniform velocity, is obtained by multiplying the time by the velocity; that is, by multiplying the space passed over in *one* second by the number of seconds that the body has been in motion. Hence, if any two of these three things, *viz.* the time, velocity, and the space passed over, be known, the third is easily obtained: for the *velocity* is equal to the space passed over divided by the *time* that the body has been in motion; and the *time* is equal to the space divided by the velocity.

The time is here supposed to be expressed in seconds, the velocity in some known measure of length, and the space in the same kind of measure.

If two bodies move uniformly on the same line in *opposite* directions, their relative velocity is equal to the *sum* of their absolute velocities; but when they move in the *same* direction, their relative velocity is equal to the *difference* of their absolute velocities. Thus, if two vessels sail from the same port, the one steering straight *north*, at the rate of ten miles per hour, and the other straight *south*, at the rate of six miles per hour, their relative velocity is sixteen miles per hour; that is, they are moving from each other at the rate of sixteen miles per hour. But if both vessels were to sail in the *same* direction, their relative velocity would be four miles per hour; that is, the one would gain four miles per hour upon the other.

HYDROSTATICS.

The science which applies the principles of Dynamics (*see* page 6.) to *fluid* bodies, is called Hydrodynamics, and is divided into four parts, according as fluids are *incompressible* or *elastic*, and according as their *equilibrium* or their *motion* is considered.*

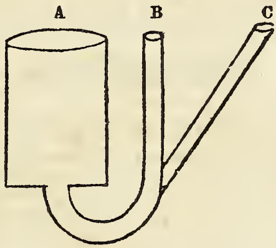
When fluids are incompressible like water, the science which explains their equilibrium is called *Hydrostatics*, and that which explains the laws of their motion is called *Hydraulics*. When they are compressible and elastic, like air, the science which treats of the laws of their equilibrium is called *Aërostatics*, and that which treats of their motion *Pneumatics*.

The surface of every fluid, when at rest, is horizontal, or level; but if it be permitted to flow freely from one vessel to another, it will never be at rest till it be the lowest possible.

If a communication, by means of a tube or pipe, either straight or crooked, be made between the water in one vessel and that in another, the surfaces of both will come to be at the same level before the water is at rest; and if there is not water

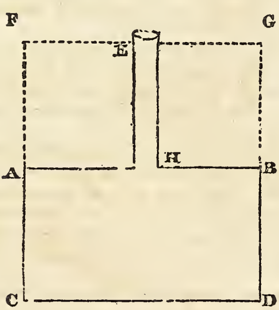
* A fluid is a body so constituted as to yield to any degree of pressure, however small, in any direction.

sufficient to bring both to a level, the whole will be accumulated in the lowest. This singular fact is easily proved, by procuring a vessel of the following form, and



pouring water into it, either by the large aperture A, or the small one B; for the water will, in both cases, stand at the same level in each of the tubes; and this will be the case, however small the one be in proportion to the other. The same thing would take place, if the small tube were made longer and inclined, like the one C. This shows that a small quantity of water may be made to balance a very large quantity.

If the liquid in any vessel be perfectly at rest, the pressure on the bottom and sides of the vessel is equal to the weight of a vertical column of the liquid having the same base as the vessel, and reaching to the surface of the water; that is, having its altitude equal to the perpendicular depth of the water. Hence, the pressure on any part of the bottom or sides of a vessel, depends entirely on the depth of the liquid at that part, and not at all on the extent of the liquid in a horizontal direction. If the figure of a vessel be as is here represented, the pressure on every point of the bottom is the same as if it were filled with liquid every where to the height of the line, F, E, G.



It is, therefore, evident that the pressure of a liquid on the bottom of a vessel may be very great, while the weight of the liquid is very small; it is also evident, that the addition of a small quantity of water, in the neck or tube H E, may increase the pressure on the bottom, C D, in a very great proportion. This is called the *Hydrostatic Paradox:* and it certainly does appear incredible, although the fact is beyond dispute, that all vessels, whatever their shape or size may be, having equal heights, and equal areas of bottom, sustain equal pressure on their bottoms, when filled with water, even though the quantity in each should be very different.

When a body is immersed in a fluid, it is pressed upwards by a force equal to the weight of the fluid which it displaces, and the direction of that force passes through the centre of gravity of the part immersed. This holds good, whether the body sink in the fluid or float on its surface: when it floats, the weight of the fluid displaced is equal to the weight of the body.

The difference between the absolute weight of a body, and its weight when entirely immersed in a fluid, is the same with the weight of a quantity of the fluid equal in bulk to the body.

Hence, the specific gravities of bodies are found by weighing them, first in air, and then in water, by means of an instrument called the *Hydrostatic Balance*, which so nearly resembles a common balance, that it is quite unnecessary to give any representation of it here. The method of determining the specific gravity of any substance by this instrument is exceedingly simple.

Suppose it were required to determine the specific gravity of a body so light as not to sink in water, by means of the Hydrostatic Balance.

Weigh the body first in air, and then by a slender thread attach to it a heavier body, that the two together may sink in water, the weight of the heavier body being previously ascertained, both in air and water. Let the compound body thus formed be weighed in water; then, from the weight lost by it, subtract the weight lost by the heavier body, when weighed alone; the remainder is the weight lost by the lighter body: by which, its weight in air being divided, will give its specific gravity.

If it were required to determine the specific gravity of a body heavier than water, the process is still more simple: for it is only to weigh the body first in air, and then in water, and to divide its weight in air by the weight it has lost when weighed in water,—the quotient is its specific gravity.

An example in each of these cases will render the method of determining the specific gravity of any substance quite plain.

Suppose a piece of elm wood to weigh

15 grains in air, and that a piece of copper, weighing 18 grains in air, when attached to the wood, is just sufficient to sink it. The sum of these weights, or the weight of the compound, is 33 grains. Now, suppose the weight of the copper alone, when weighed in water, to be 16 grains, and the weight of the compound 6 grains. The loss of the compound is therefore 27 grains; from which the 2 grains, lost by the copper, being subtracted leaves 25 grains; now the weight of the wood, in air (15 grains), being divided by this number, quotes ·6, or 3-fifths for the specific gravity of the elm.

Let it now be required to determine the specific gravity of a substance which sinks in water.

Suppose a piece of gold weighs 130 grains in air, but in water only 123 grains, the difference of these weights, or the weight lost in water is 7 grains. Now the weight in air, or 130 grains divided by 7, quotes 18 and 4-sevenths, the specific gravity of the gold, in this instance.*

If the same body be weighed in two different fluids, such as oil and water, the weights lost will be to one another as the specific gravities of the fluids; that is, the lighter the fluid is, in which any body is weighed, the greater will be the difference between the weight of the body weighed in air and in that fluid.

The knowledge of this circumstance affords the means of comparing the specific gravities of different fluids with each other.

Thus: suppose a piece of copper lost 4 grains by weighing it in water, and $3\frac{1}{2}$ in spirits; required the specific gravity of the spirits, that of water being considered 1000? As $4 : 3\frac{1}{2} :: 1000 : \cdot 875$, the specific gravity of the spirits.

The specific gravities of different fluids may also be found, by weighing equal bulks of them.

If a body float on different fluids, the bulks of the part immersed will be the greater, the lighter the fluid is in which it is immersed; because a light fluid is less able to support it than a heavy fluid. It is on this principle that the Hydrometer, Aërometer, &c. are constructed.†

In the foregoing directions, for determining the specific gravity of any body, no notice has been taken of the weight of the air; because the weight of a body, when weighed in *vacuo*, or in a vessel from which the air has been extracted, and when weighed in air will be so nearly equal, that the difference is scarcely deserving of notice.

* As Tables of the specific gravities of bodies are of great use, a very extensive and accurate Table of this kind will be given in a future Number of the "ARTISAN."

† The Hydrometer is an instrument used for ascertaining the specific gravities of liquids, and the Aërometer for ascertaining the specific gravity of air. These instruments will be described in a future Number.

PNEUMATICS.

THAT branch of Natural Philosophy which treats of the nature, properties, and effect of the atmosphere, or body of air encompassing the earth, is called Pneumatics, from the Greek word for wind or breath.

The air is that thin transparent fluid in which we live and move. It encompasses the whole earth to a considerable height, and together with the clouds and vapours which float in it, is called the atmosphere. The air is justly reckoned among the number of fluids, because it has all the properties by which a fluid is distinguished; for it yields to the least pressure, its parts are easily moved among themselves, it presses according to its perpendicular altitude, and its pressure is every where equal.

The air differs from all other fluids in the three following particulars :—1st. It can be compressed into much less space than it naturally occupies, which no other fluid can be, except the gasses, which will be treated of under the head of Chemistry. 2d. It cannot be congealed or fixed like other fluids. 3d. It is of a different density at different heights from the earth's surface, decreasing the higher it rises; for each stratum is compressed only by the weight of those above it; the upper strata are therefore less compressed, and of course less dense, than those below them.

That the air is a real substance, or body, is evident, from its excluding all other bodies from the space which it occupies: for if a glass jar be plunged into a vessel of water, with its mouth downwards, very little water will get into the jar, the air in it keeping the water out.

As the air is a real substance, it must necessarily have weight; and that this is the case, is easily demonstrated by experiment. For if the air be extracted from a vessel by means of the air pump, and the vessel afterwards weighed, it will be considerably lighter than it was before the air was extracted; or which amounts to the same thing, it will be considerably heavier after the air is again let into it. Thus a bottle that contains a wine quart will be found to be 18 grains heavier when full of air, than when the air is extracted from it.

The weight of the air is also known by the Torricellian experiment, or that of the barometer. For the air presses on the orifice of the inverted tube with a force just equal to the weight of the column of mercury sustained by it.

The pressure or weight of the atmosphere is about 14 pounds on every square inch of the earth's surface. Hence the total pressure on the whole convex surface of the earth is 10,686,000,000,000,000 pounds.

The air being of an elastic or springy nature, it is plain that it must be more dense or pressed at the earth's surface than at any considerable height above it; and that the greater the height the less must be the density. The *law* by which the density and elasticity diminish has been determined by several philosophers, and may be stated thus: if altitudes be taken from the earth's surface in arithmetical progression, the densities of the strata of air will decrease in geometrical progression. For example, at 3½ miles height the density or weight of the air will be only half what it is at the earth's surface; at 7 miles height, one-fourth of the density; at 10½ miles, one-eighth of the density; at 14 miles, one-sixteenth part of the density, and so on.

From the effect of this law it is easy to perceive that a small quantity of air, a cubic inch, for example, at the earth's surface, would be so much rarefied at the altitude of 500 miles, as to occupy a most extraordinary space. It must also be evident that no person could breathe or live for a moment at so small a height as 20 miles, or even at the top of some of the mountains on the earth, none of which exceed five miles in height.

When the end of a tube, or pipe, is immersed in water, and the air extracted from the tube, the water will rise in it to the height of about 33 feet above the surface of the water in which it is immersed, but will rise no higher; and this is the greatest height to which water can be raised above the surface of a well by the common pump: therefore, unless the piston or bucket goes within 33 feet of the surface of the water in a well, it will never rise above the piston. Now as it is the pressure of the atmosphere on the surface of the water in the well which causes the water to ascend in the pump, and follow the piston or bucket when the air above it is lifted up, it is evident that a column of water 33 feet high is equal in weight to a column of quicksilver of the same base, 29½ inches high, and to a column of air having the same base, and reaching to the top of the atmosphere.

In calm serene weather the air is capable of supporting a column of quicksilver 31 inches high; but in rainy or stormy weather often not above 28 inches. Hence the rising and falling of the quicksilver in the tube of a barometer is an excellent indicator of the changes which take place in the weight of the atmosphere.

In all that has been said of the weight of the air, its temperature is supposed to remain unchanged; but it is well known that this is not the case for any length of time, and that its density is very much diminished by heat.

The temperature of the air diminishes on ascending into the atmosphere, both on account of the greater distance from the earth, the principal source of its heat, and the greater power of absorbing heat, which air acquires by being less compressed.

The heat, however, appears not to decrease in the same ratio that the distance increases. That is, the temperature at any particular height from the earth is not double what it is at twice that height.

M. de Saussure found, that by ascending from Geneva to Chamouni, a height of 347 *toises*, or about 2220 feet, Fahrenheit's thermometer fell 9½ degrees; and that on ascending from thence to the top of Mont Blanc, 1941 *toises* more, or about 12,500 feet, it fell 46½ degrees. The first of these gives a diminution of 1 degree for 221 feet; and the second 1 degree for 268 feet. However, it may be inferred that the decrease of temperature, for the greatest heights which we can reach, is not far from uniform; and the average in our climate may be taken at 1 degree for 90 yards, or 270 feet of perpendicular height. But philosophers are not agreed respecting the rate at which the heat of the atmosphere diminishes in ascending from the earth's surface. La Grange thinks that the hypothesis of a uniform decrease of heat is the most conformable to appearances; while Euler considers a harmonical progression as the most probable.

OPTICS.

Optics is divided into two parts:—

1. *Catoptrics*, which treats of vision by reflection.

2. *Dioptrics*, which treats of direct vision.

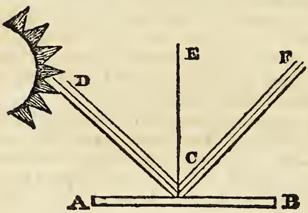
Some philosophers regard light as consisting of particles of inconceivable minuteness, flowing from some luminous body, in straight lines in all directions.

Others conceive that it consists in certain undulations, or waves, communicated by luminous bodies to an etherial fluid which fills all space. With these speculations, Optics has no more to do than Astronomy has with speculations concerning the nature of gravitation.

That the rays of light move in straight lines is proved beyond the possibility of doubt, from the fact that no body can be seen through the bore of a bended tube or pipe, where there is nothing to refract or turn them out of their rectilineal course.

When the rays of light fall upon the surface of bodies, they are in part *reflected* from those surfaces, and in part imbibed by them, or pass through them. The rays that are reflected always return or pass off from those surfaces at an angle equal to that at which they fell upon them; which is usually expressed by saying that the angle of *incidence* is equal to the angle of *reflection.*

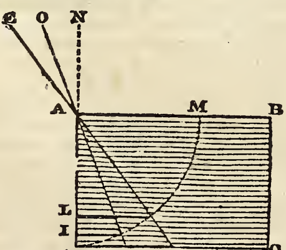
This will be eastly understood by a moment's observation of the following figure.



If A B be supposed to be the surface of a plain mirror, D C a ray of light falling on it at C, then will the ray D C be reflected in the direction C F, making the angle D C E (called the angle of *incidence*), equal to the angle E C F, or angle of reflection.

It has already been stated that the rays of light pass from luminous bodies in straight lines; but they continue only in this direction while the medium in which they are moving remains of the same density; but when they pass obliquely out of one medium into another of a different density, whether denser or rarer, they are *refracted* towards the denser medium: and this refraction is the greater the more obliquely the rays fall on the refracting surface.*

This is very easily proved by experiment in the following manner:



Let the vessel A B C D be placed in any situation where the sun shines obliquely upon it in the direction E F, and let the rays enter it at the top of the side A D, they will fall on the bottom at F. Let the vessel now be filled with water, and the rays E A will not proceed through the water to F as before, but will be turned downward in the direction A G, which is therefore termed the *refracted ray;* the angle D A G is also called the angle of *refraction;* and the angle D A F the angle of *incidence.*

These angles bear the same proportion to each other as the straight lines I and L, which are called the *sines* of these angles; and are to each other as 3 to 4 nearly in water, 2 to 3 in glass, and 2 to 5 in diamond.

If a stick be laid over the above vessel, and the rays be refracted by means of a glass so as to fall upon it perpendicularly, the shadow of the stick will fall upon the same part of the bottom when the vessel is full of water, as when it is empty; which shews that the rays of light are not refracted when they fall perpendicularly on the surface of any medium.

Another very amusing method of proving that the rays of light are refracted in passing out of air into water is the following:—Place a piece of money in a cup or basin, and let a person stand at such a distance from it as barely not to see the money; then fill the basin with water, and the money will appear to be raised up to a considerable height in the basin, and become distinctly visible to the person who could not perceive it before the water was poured into the basin.

In consequence of the atmosphere being much denser at the surface of the earth than at considerable altitudes, (see Pneumatics) the rays of light which proceed from any celestial body are refracted from their rectilineal course, and enter the eye in a direction somewhat different from that in which the object really is. This refractive power of the atmosphere has the effect of making all the heavenly bodies appear higher than they really are. Hence the moon has been seen eclipsed when she was actually under the horizon of the place. This is also the cause of twilight; and of the light of the sun being seen, in high latitudes, when he is several degrees below the horizon.

Rays of light are usually divided into three kinds; namely, parallel, converging and diverging rays. *Parallel* rays are such as keep always at the same distance in passing from a luminous body to any other body, such as the rays of the sun, or any body at an immense distance. *Converging* rays are such as approach nearer to each other in their progress. *Diverging* rays

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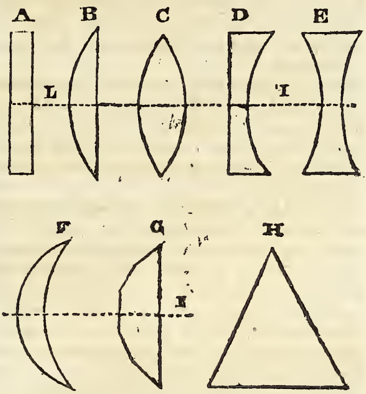
* The word *medium* here means a substance which permits the rays of light to pass through it, such as air, water, glass, &c.

Words which have once been explained in any part of this work, will not again be explained in any other part.

are such as recede or separate from each other as they proceed from any luminous body. That point where the rays are condensed or collected is called the *focus*, or burning point.

Glasses, for optical purposes, are ground into eight different forms, which are all exhibited in the following figure :—



1. The one marked A is a *plane glass*, which is flat on both sides, and of equal thickness in all parts.

2. A *plano-convex* is flat on one side, and convex or raised on the other, as B.

3. A *double-convex*, is convex on both sides, as C.

4. A *plano-concave*, is flat on one side, and concave or hollow on the other, as D.

5. A *double-concave*, is concave on both sides, as E.

6. A *meniscus*, is concave on one side, and convex on the other, as F.

7. A flat plano-convex, is plane on one side, and its convex side is ground into several little flat surfaces, as G.

8. A *prism* has three flat sides, and when viewed endwise, appears like an equilateral triangle, as H.

Glasses ground in any of the shapes B, C, D, E, F, are generally called *lenses*.

A right line going perpendicularly through the middle of a lens, as L I, is called the axis of the lens.

When a ray of light falls *perpendicularly* on a plane glass, it passes through the glass without changing its direction.

If a ray fall *obliquely* upon a plane glass, it will be refracted on entering the glass; but on passing out of the glass it will then proceed in the original direction, but not in the same right line ; that is, it will proceed in a line parallel to the one in which it moved previous to entering the glass. This change proceeds from the refraction occasioned by the glass.

CHEMISTRY.

HISTORY OF CHEMISTRY.

Chemistry, considered as an Art, is of the earliest origin; but, considered as a *Science*, it may be said to be of very modern date. The method of kindling *fires*, baking *bread*, moulding *clays* into various forms, extracting *metals* from their *ores* and working them into different shapes, as well as several other chemical processes, were certainly known to the Antediluvians.

Tubal Cain, who is mentioned in Scripture, and whom the Pagans made their Vulcan, is the first person on record who knew any thing of this art.

It is said, " he was a worker in Iron and Brass :" he must, therefore, have known something of Chemistry before he could have extracted metals from their ores, and rendered them malleable.

It appears that, soon after the Deluge, the family of *Ham* made great progress in the Art. For the Egyptians, whose country is called Ham in Scripture, and who are said to be the descendants of *Ham*, applied themselves very much to this branch of study, and made many discoveries; such as Embalming the bodies of the *dead*, making *Vases*, fabricating a kind of Nitre, making common Salt, and even *Wine* ; and, it is said, they knew the art of distillation.

It was in Egypt that the famous Hermes Trismegistus lived, who has been regarded by many heathen nations as the inventor of *all* the arts. He is said to be the Author of all the learning of the Egyptians, and believed by many to have been Chanaan, son of Ham, or Abraham, or Joseph.

From this person the Science of Chemistry derived the name of the *hermetical Art ;* a name which it was long known by, and is often called so in old books.

It was in Egypt that Moses learned the properties of Metals, the method of extracting Oils, the preparation of Gums and Perfumes, the solution of Gold, the dying of Linen, the art of Gilding, the making of Pottery, Soap, &c.

The Phœnicians were the first who applied themselves to the examination of the chemical effects of different bodies upon each other; and it is said the Grecians derived their arts which depend on chemical principles from the Phœnicians.

The Romans being mostly engaged in war, were not distinguished among the ancient nations for discoveries in the arts, or inventors in science. They, however, understood the art of making excellent *Wines* and *Spirits*, and knew the application of manures; and the remains of their works of Architecture evince the incomparable perfection of their Cement.

But all the *Arts*, *Sciences*, and *Lite-*

rature, of the Greeks and Romans, were destined to sink into *oblivion*. Hosts of barbarian conquerors descended upon them from the North, and completely destroyed the principles of civilization, and gave a death-blow both to science and literature.

Driven as it were from Europe, the arts obtained an asylum among the Arabians. The attachment of this nation to magic, and their predilection for the marvellous, soon increased the mysteries in which the arts were then involved; hence Alchymy, or the art of transmuting the various metals into gold, took its rise. This happened about the beginning of the fourth century. As this delusive dream of the imagination held out a bait to avarice, it soon acquired a numerous train of followers.

Those who professed this *Art*, gradually assumed the form of a Sect, under the name of Alchymists; a term which is supposed to be merely the word Chemist with the Arabian article *al* prefixed.

The Alchymists laid it down as a first principle, that all metals are composed of the same ingredients; or, that the principles (at least) which compose gold *exist* in all *metals*, and were capable of being brought to a perfect state by purification.

The substance which possessed this wonderful property, they called *lapis philosophorum*, or the " Philosopher's Stone ;" and many of them boasted that they were in possession of that grand instrument.

The fortunate few who were acquainted with the philosopher's stone, called themselves *adepti*, or adepts; that is, persons who had got possession of the secret.

This secret, they pretended, they were not at liberty to disclose, and that vengeance would fall on the man's head who should *venture* to publish it.

In consequence of these notions, the Alchymists kept themselves as private as possible; and concealed with the greatest care, their *opinions*, their knowledge, and their pursuits.

The Alchymists seem to have been established in the West of Europe as early as the ninth century.

Between the *eleventh* and *fifteenth centuries*, Alchymy was in its most *flourishing* state. The writers who appeared during that period were very numerous; but their books are altogether unintelligible, and bear a stronger resemblance to the reveries of madmen, than to the sober investigations of philosophers.

The principal Alchymists who flourished during the dark ages were Albertus Magnus, Roger Bacon, Raymond Lully, and the two Isaacs of Holland. It was against this sect that Erasmus directed his well-known Satire, entitled the Alchymist.

Chemists had for many ages hinted at the importance of discovering a universal remedy for all diseases, and several of them had asserted that this remedy was to be found in the philosopher's stone. This notion gradually gained ground; and the word Chemistry, in consequence, at length, acquired a more extensive signification, and implied, not only the art of making *gold*, but also of preparing the universal Medicine. The first person who formally applied Chemistry to medicine, was Basil Valentine, who was said to be borne in 1394, at Erfurd, in Germany.

Just about the time that the first of these branches was sinking into discredit, the second, and with it the study of *Chemistry*, acquired an unparalleled degree of celebrity, and attracted the attention of all Europe. This was owing to the appearance of Theophrastus Paracelsus, who was born in 1493, near Zurich, in Switzerland, and was, in the thirty-fourth year of his age, appointed to read lectures on Chemistry in the city of Basil. He was the first professor of Chemistry in Europe.

Van Helmont, who was born in 1577, is considered as the last of the Alcyhmists. His death completed both the disgrace of the philosopher's stone and the universal medicine.

The foundation of the alchymical system being thus shaken, the facts which had been collected soon became a mere chaos, and Chemistry was left without any fixed principles, and destitute of any object. But, fortunately, about this time, arose a person completely acquainted with the whole of these facts, and rescued this branch of science from the oblivion into which it would soon have fallen. This person was the celebrated Beccher. He accomplished the arduous task in a work entitled *Physica Subterranea*, published at Frankfort in 1669. The publication of this book forms a very important æra in the history of Chemistry, as it contains the rudiments of the science as taught at the present day. After the death of Beccher, Ernest Stahl, the editor of the Physica Subterranea, adopted and taught the theory of his master: but he simplified and improved it so much, that he made it entirely his own: and accordingly it has been known ever since by the name of the *Stahlian Theory*.

Ever since the days of Stahl, Chemistry, has been cultivated with ardour in Germany and the *North of Europe*. The most celebrated men which these countries have produced are, Margraf, Bergman, *Sheel*, and Klaproth.

In France, soon after the establishment of the Academy of Sciences in 1666, Homberg, Geoffrey, and Lemery, acquired great celebrity by their chemical experiments and discoveries.

From that time Chemistry became the

fashionable study in France, and men of eminence appeared every where; discoveries multiplied; the spirit for chemical research pervaded the whole of that kingdom, and extended itself over the continent of Europe. After the death of Boyle, and some of the other *early* members of the Royal Society of London, little attention was paid to Chemistry in Britain, except by a few individuals. But when Dr. Cullen was appointed Professor of Chemistry in the University of Edinburgh, in 1756, he kindled a flame of enthusiasm among the students, which soon spread through the kingdom; and, after this, soon followed the important discoveries of Dr. *Black*, *Cavendash*, and *Priestly*, which, joined to the discoveries made in France, Germany, and Sweden, made the science of Chemistry burst forth at once with unexampled lustre. Hence, the rapid progress it has made during the last thirty years; the universal attention which it has excited, and the unexpected light it has thrown on almost every useful art.

Having thus given a short but comprehensive view of the history of Chemistry down to our own times, we shall conclude this article by taking a retrospective view of some of the most distinguished THEORIES of the ANCIENTS, the various modifications which they have undergone at different times, and the steps by which chemists have been led to the opinions which they hold at present.

It seems to have been an opinion established among the most ancient philosophers, that there are only *four* simple bodies, out of which all others are formed, or to which all others may be reduced; *viz. fire, air, water, and earth.* To these they gave the name of *Elements*.

This opinion variously MODIFIED was maintained by *all* the ancient philosophers. It is, however, well known now that all these supposed *elements* are compounds if we except fire.

Air is a compound of oxygen and nitrogen; water, of oxygen and hydrogen; and earth, of many different substances.

The doctrine of the four elements seems to have continued undisputed till the time of the Alchymists.

This class of men having made themselves much better acquainted with the analysis of bodies than the ancient philosophers were, soon perceived that the common doctrine was insufficient to explain all the appearances which were familiar to them. They therefore substituted a theory of their own in its place. According to them there are *three elements* of which all bodies are composed; namely, *salt*, *sulphur*, and *mercury*, which they distinguished by the appellation of the *tria prima*. These principles were adopted by succeeding writers, particularly by Paracelsus, who added two more to their number, namely, phlegm and *caput mortuum.*

It is not easy to say what the alchymists meant by *salt*, *sulphur*, and *mercury;* it is probable they had affixed *no precise* meaning to the words.

Every thing fixed in the fire *(i. e.)* on which the fire had little or no effect, they called *salt;* every inflammable substance they called *sulphur;* and every substance which flies off without burning was *mercury*. Accordingly they tell us, that all bodies may be decomposed by fire, into these three principles; the salt remains behind fixed, the sulphur takes fire, and the mercury flies off in the form of smoke. The phlegm and *caput mortuum* of Paracelsus were the *water* and *earth* of the ancient philosophers.

Mr. Boyle attacked this hypothesis in his *Sceptical Chemist*, and in several *other* of his publications, and proved that the Chemists comprehended under each of the terms salt, sulphur, mercury, phlegm, and earth, substances possessed of very *different properties;* and that these principles themselves are not *elements* but *compounds*.

Mr. Boyle's refutation was so complete, that the hypothesis of the *tria prima* seems to have been almost immediately abandoned by *all* parties. About this time a very different hypothesis was proposed by Beccher, in his *Pysica Subterranea*, which has been already mentioned.

To this hypothesis we are indebted for the present *state* of the *science*, because he first pointed out chemical ANALYSIS, as the true method of ascertaining the *elements* of bodies.

According to him all terrestrial bodies are composed of *water*, *air*, and three earths; viz. the fusible, the *inflammable*, or sulphurous earth, and the *mercurial*. The different combinations of these, with a universal *acid* (which he believed to be composed of *fusible earth* and *water*), composed all the different substances which are to be met with in nature.

Stahl modified the theory of Becher considerably. He seems to have admitted the universal acid as an element; the mercurial *earth* he at last discarded altogether, and to the *sulphurous earth* he sometimes gave the name of *ether*.

Earths he considered as of different kinds, but all of them as containing a certain element called *earth*. So that according to him there are *five elements;* air, water, phlogiston, earth, and the universal acid. He speaks too of *heat* and *light;* but it is not clear *what* his opinion was respecting them.

Stahl's theory was gradually modified by succeeding chemists.

The universal acid was tacitly discarded, and the different *known acids* were considered as distinct, undecomposed, or simple substances: the different *earths* were distinguished from each other, and all the metalic *calces* were considered as distinct substances.

For these important changes Chemistry was chiefly indebted to Bergman. While the French and German chemists were occupied with theories about the universal acid, that illustrious philosopher and immortal friend of Bergman's (Scheele of Sweden) loudly proclaimed the necessity of considering every undecomposed body as simple, till it has been decomposed, and of distinguishing all those substances from each other which possess distinct properties.

Thus the elements of *Stahl* were, in fact, *banished* from the science of Chemistry, and in place of them were substituted a great number of bodies, which were considered as *simple*, because they had not been analyzed. These were phlogiston, acids, alkalies, earths, metalic calces, water, and oxygen.

The rules established by Bergman and Scheele are still followed; but subsequent discoveries have shewn, that most of the bodies which they considered as *simple*, are really compounds; while several of their *compounds* are now placed among *simple bodies*, because the doctrine of phlogiston (in which they believed) is now entirely abandoned.

ASTRONOMY.

HISTORY OF ASTRONOMY.

No science in the world is of more value, or of higher antiquity, than Astronomy. Its antiquity may be learned from what was spoken by God himself at the creation of the world; for He said—"Let the sun and the moon be for signs and for seasons," &c.

By this it is thought the human race never existed without some knowledge of Astronomy among them. It is said by some Jewish Rabbins, that Adam was endowed with a knowledge of the nature, influence, and uses of the heavenly bodies; and Josephus ascribes to Seth and his posterity an extensive knowledge of Astronomy.

It is supposed, by some writers, that Noah retired after the flood to the north-east part of Asia, where his descendants peopled the vast empire of China. "This," says Dr. Long, "may account for the Chinese having so early cultivated the study of Astronomy." But the vanity of the Chinese has prompted them to pretend to a knowledge of this science almost as early as the flood itself.

To the emperor Hoang-ti, the grand-son of Noah, they attribute the discovery of the Pole star and the mariner's compass. They also say, that Confucius, their great philosopher, who lived 551 years B. C. has recorded 36 eclipses; but be this as it may, the Chinese are allowed to have had a very early knowledge of Astronomy.

Some authors say it had its origin among the Chaldeans, others among the Hindoos, and some, with more probability, among the Egyptians. Professor Playfair has given a learned and ingenious dissertation on the Astronomy of the Brahmins, in the 2d volume of the Transactions of the Royal Society of Edinburgh, in which he shews the great accuracy and high antiquity of the science among them; and he also shows that it is extremely probable that the Hindoos were among the first Astronomers in the world.

But Thales of Miletus is considered as the first person that propagated any truly scientific knowledge of Astronomy; and it is said he acquired his knowledge of the subject in Egypt.

Thales taught his countrymen the cause of the inequality of the days and nights; explained to them the theory of eclipses, and the manner of predicting them; and gave them an example of his art in an eclipse of the sun, which happened soon after: he was born about 640 years B. C. Anaximander was a pupil of Thales, and succeeded him as head of the school of Miletus. It is said he had some idea of the spherical shape of the earth; he is also said to have been the inventor of celestial globes, and of the orthographic projection of maps. He constructed a gnomon at Sparta, by which he ascertained the obliquity of the ecliptic, with the solstices and equinoxes.

Pythagoras was the next person who improved the science. He founded a school in Italy for that very purpose. Seconded by his earliest scholars, he clearly demonstrated the spherical shape of the earth, which Anaximander had only conjectured. Pythagoras taught that the sun was fixed in the centre of the planetary orbits, and that the earth moved round it with the other planets—the very system which is taught at this day. This opinion he communicated only to his pupils in secret; for being repugnant to the received opinions of that time, (and even appearances,) he did not wish to expose himself to the derision and persecution of ignorance and fanaticism, which would have been the inevitable consequence. For about 100 years after his time, Anaxagoras was condemned to banishment for saying that the sun was a mass of fiery matter. The measuring of time being a principal object in Astronomy, many efforts were made by the ancients to determine accurately, and to compare with each other, the motions of the sun and moon, on which this measure universally depends.

[*To be continued.*]

GEOMETRY.

POSTULATES.*

A POSTULATE is a self-evident practical Proposition.

The Postulates are, however, not to be so understood, as if Euclid required a practical dexterity in managing a ruler and pencil, or a pair of compasses. They are inserted at the beginning of the Elements, that his readers may admit the *possibility* of what he may hereafter require to be done. He therefore enumerates all the operations required in his future demonstrations and problems, requiring their possibility to be acknowledged in order to avoid all future objections on this head.

The Postulates are three in number; *viz.*

1. Let it be granted that a straight line may be drawn from any one point to any other point.

2. That a terminated straight line may be produced to any length in a straight line.

3. That a circle may be described from any centre, at any distance from that centre.

AXIOMS.

An Axiom is a self-evident *theoretical* proposition, which neither admits of nor requires proof: it may require to be explained in order to be made intelligible; but as soon as understood, it should be what all immediately assent to.

Axioms evidently depend, in the first instance, on particular observation, from whence the mind intuitively perceives their truth in general: like the postulates, after they have been once laid down and acknowledged, they are applied to the proof of the demonstrable propositions which follow in the Elements.

The axioms laid down by Euclid are the following:—

1. Things which are equal to the same thing, are equal to one another.

2. If equals be added to equals, the wholes are equal.

3. If equals be taken from equals the remainders are equal.

4. If Equals be added to unequals, the wholes are unequal.

5. If equals be taken from unequals, the remainders are unequal.

6. Things which are double of the same, are equal to one another.

7. Things which are halves of the same, are equal to one another.

8. Magnitudes which coincide with one another, that is, which exactly fill the same space, are equal to one another.

9. The whole is greater than its greatest part.

10. Two straight lines cannot enclose a space.

11. All right angles are equal to one another.

12. If a straight line meets two straight lines, so as to make the two interior angles on the same side of it taken together less than two right angles, these straight lines being continually produced, shall at length meet upon that side on which are the angles which are less than two right angles.

The first ten axioms are too plain to require illustration; the eleventh is what is usually called an identical proposition, for it amounts to no more than this, "all right angles are right angles."

The 12th axiom is not properly an axiom, but a proposition which requires proof; therefore, if the reader does not fully comprehend its import, he may substitute the following simple proposition in its stead.

Two straight lines meeting in a point, are not *both* parallel to a third line.

PROPOSITIONS.

In a geometrical proposition, something is either proposed to be *done*, or some truth is to be *demonstrated**.

In the former case the proposition is called a *Problem*; in the latter, it is a *Theorem*.

Euclid, in his Elements, employs two methods of demonstrating his propositions; namely, *direct* and *indirect*.

A *direct demonstration* is that which proceeds from acknowledged truths, by a chain of successive inferences, the last of which is the thing to be proved.

An *indirect demonstration*, or, as it is often termed, *Reductio ad Absurdum*, consists in assuming as true, a proposition which directly contradicts the one which is intended to be proved; and by proceeding on this assumption, in the same manner as in the direct method, we at length deduce an inference which contradicts some self-evident or previously demonstrated truth; the assumption is therefore absurd and false;—consequently the proposition we intended to prove must be true, since two *contrary* propositions cannot be both true or both false at the same time.

As the *converse* of some propositions are true, and of others not, it may be proper

* The word postulate literally means a petition, or request.

* A subordinate property included in a demonstration, is sometimes stated in a detached form, and is then called a *Lemma*.

An obvious consequence that results from a proposition is called a *Corollary*.

An excursive remark on the nature and application of a demonstrated proposition is called a *Scholium*.

to inform the reader that the converse of a proposition is not necessarily true,—therefore, when it is so, it requires demonstration; and accordingly Euclid demonstrates such as he has occasion for.* The converse of the 5th is true, and it is demonstrated to be so in the 6th. But the converse of the 8th proposition, for example, is not true. For though all triangles having their sides respectively equal, have their angles also equal; yet all triangles which have their angles equal have not their sides equal.

It may also be of use to inform the student of Geometry, that every proposition consists of three distinct particulars; viz. the *Enunciation*, the *Construction*, and the *Demonstration*. The enunciation declares in general terms what is intended to be done or proved. The construction teaches how to draw the necessary lines, circles, &c. and applies the enunciation to the figure thus constructed. The demonstration is the chain of reasoning that follows, whereby what was enunciated is clearly and fully proved.

Before the demonstration of any proposition is attempted, the enunciation should be well understood, and even got by heart. The figure should then be constructed solely by the directions which immediately follow the enunciation; and the more accurately this is done, the better will it assist the recollection: compasses, &c. *may* be employed for this purpose, but they are not *absolutely* necessary, for the truth of any proposition does not in the least depend on the accuracy of the construction.

Previous to beginning with the propositions, of Euclid's Elements, we may remark, for the information of those who are unacquainted with that valuable work, that we shall endeavour to render these propositions as simple as it is possible to make them; but we must also remark, that there are many of these which it is impossible to render more simple; and that there are certain principles or mathematical truths that do not admit of being rendered more clear or more intelligible than they appear by merely enunciating them.

The greatest assistance we can give the student in this branch of science, will be found in the observations and notes upon the propositions to which they are subjoined.

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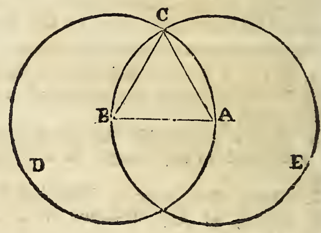
* *Converse* and *contrary* propositions are not to be confounded, as is often done: the contrary proposition is, when what is affirmed in the former proposition is denied in the latter. Thus the contrary of proposition 5th is this, that the angles at the base of an isosceles triangle are not equal: now the converse of this proposition is demonstrated to be true in the 6th proposition.

PROPOSITION I.

Problem:—*To describe an equilateral triangle upon a given straight line.*

Let A B be the given straight line; it is required to describe an equilateral triangle upon it.

From the centre A, at the distance A B, describe the circle B C E; and from the centre B, at the distance B A, describe the circle A C D; and from the point C, in which the circles cut one another, draw the straight lines C A, C B, to the points A and B; A B C shall be an equilateral triangle.*



Because the point A is the centre of the circle B C E, A C is equal to A B; and because the point B is the centre of the circle A C D, B C is equal to B A. But it has been proved that C A is equal to A B; therefore C A, C B, are each of them equal to A B: but things which are equal to the same are equal to one another; therefore C A is equal to C B; wherefore C A, A B, B C, are equal to one another; and the triangle A B C is therefore equilateral,—and it is described upon the given straight line A B, which was required to be done.

PROPOSITION II.

Problem:—*From a given point to draw a straight line equal to a given straight line.*

Let A be the given point, and B C the given straight line; it is required to draw from the point A a straight line equal to B C.

From the point A to B draw the straight line A B; and upon it describe the equilateral triangle D A B, and produce the straight line D A, D B, to E and F; from the centre B, at the distance B C, describe the circle C G H, and from the centre D,

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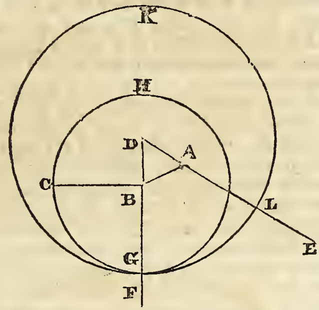
* It may be proper to remark, that in the following propositions a comma is often used for the word *and*, to prevent its repetition, as in most editions of Euclid.

at the distance D G, describe the circle G K L, A L shall be equal to B C.



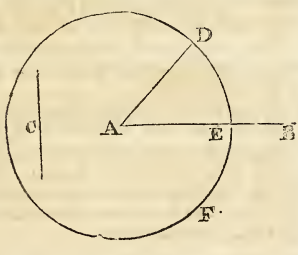
Because the point B is the centre of the circle C G H, B C is equal to B G; and because D is the centre of the circle G K L, D L is equal to D G, and D A, D B, parts of them, are equal; therefore the remainder A L is equal to the remainder B G. But it has been shown, that B C is equal to B G; wherefore A L and B C are each of them equal to B G; and things that are equal to the same, are equal to one another; therefore the straight line A L is equal to B C. Wherefore, from the given point A a straight line A L has been drawn equal to the given straight line B C.—Which was to be done.

PROPOSITION III.

PROBLEM :—*From the greater of two given straight lines to cut off a part equal to the less.*

Let A B and C be the less given straight lines, whereof A B is the greater. It is required to cut off from A B, the greater, a part equal to C, the less.

From the point A draw the straight line A D equal to C, and from the centre A, and at the distance A D, describe the circle D E F.



Because A is the centre of the circle D E F, A E is equal to A D; but the straight line C is likewise equal to A D; whence A E and C are each of them equal to A D; wherefore the straight line A E is equal to C, and from A B, the greater of the two straight lines, a part A E has been cut off equal to C, the less. Which was to be done.

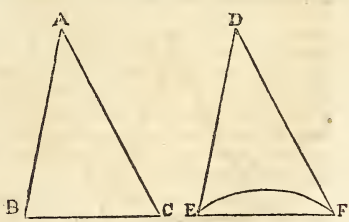
The three foregoing propositions may appear to some as very trifling—because any person who knows what a rule, and compasses are, can set off a straight line of a given length from a given point. But Euclid's design is not solely to teach the practical delineation of figures, but to derive the possibility of doing so in idea from the postulates and axioms before laid down without regard to their being easy or difficult.

If these propositions, simple as they are, be well understood, and readily demonstrated by the student of geometry, it will be the means of giving him a habit of strict and accurate reasoning, of strengthening and enlarging the powers of his mind, and of enabling him to demonstrate, with ease and facility, the most difficult propositions in the Elements.

PROPOSITION IV.

THEOREM.—*If two triangles have two sides and the included angle of the one, equal to two sides and the included angle of the other, the triangles are equal in every respect.*

Let A B C, and D E F, be two triangles, which have the two sides, A B and A C, equal to the two sides D E and D F, each to each; viz. A B to D E, and A C to D F; and the angle B A C equal to the angle E D F, the base B C shall be equal to the base E F; and the whole triangle A B C to the whole triangle D E F; and the other angles, to which the equal sides are opposite, shall be equal to each other; viz. the angle A B C to the angle D E F, and the angle A C B to D F E.*



For if the triangle A B C be applied to D E F, so that the point A may be on D, and the straight line A B upon D E, the point B shall coincide with the point E; because A B is equal to D E, and A B coinciding

* As every triangle has three sides and three angles, each angle must have a side opposite to it, and each side an angle opposite to it. Thus, in the triangle A B C, the side A C is opposite to the angle at B; and the angle at C is opposite to the side A B. This, though simple, must be carefully attended to, and if this is done, it will tend very much to render the demonstration of the next proposition more easily understood.

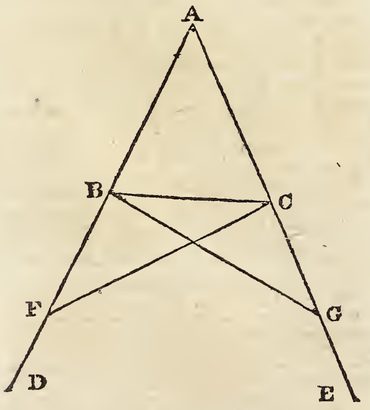
with D E, A C shall coincide with D F, because the angle B A C is equal to the angle E D F; wherefore the point C shall coincide with the point F, because the stright line A C is equal to D F: but the point B coincides with the point E; wherefore the base B C shall coincide with the base E F, because the point B coinciding with E, and C with F, if the base B C does not coincide with E F, two straight lines would inclose a space; which is impossible. (see Ax. 10.) Therefore, as the base B C coincides with the base E F, the whole triangle A B C shall coincide with the whole triangle D E F, and be equal to it; and the other angles of the one shall coincide with the remaining angles of the other, and be equal to them; viz. the angle A B C to the angle D E F, and the angle A C B to D F E. Q. E. D.*

This and the eighth are important propositions, for on them depends the whole doctrine of triangles; they are both proved by *superposition*— a mode of demonstration which has been objected to by some celebrated mathematicians; not from any want of evidence, but because they considered it not strictly geometrical, as it depends upon no *postulale.*

PROPOSITION V.

THEOREM.—*The angles at the base of an Isosceles Triangle are equal to one another; and, if the equal sides be produced, the angles upon the other side of the base shall be equal.*

Let A B C be an isosceles triangle, of which the side A B is equal to A C, and let the straight lines A B and A C be produced to D and E, the angle A B C shall be equal to the angle A C B, and the angle C B D to the angle B C E.



In B D take any point F, and make A G equal to A F, and join F C and G B.

Because A F is equal to A G, and A B to A C, the two sides F A and A C are equal to the two sides G A and A B, each to each; and they contain the angle F A G, which is common to the two triangles A F C and A G B; therefore (by the 4th prop.) the base F C is equal to the base G B, and the whole triangle A F C to the whole triangle A G B; and the remaining angles of the one to the remaining angles of the other, each to each, to which the equal sides are opposite; viz. the angle A C F to the angle A B G, and the angle A F C to the angle A G B: and because the whole A F is equal to the whole A G, of which the parts A B and A C, are equal; the remainder B F shall be equal to the remainder C G; and F C was proved to be equal to G B; therefore the two sides B F and F C are equal to the two C G and G B, each to each; and the angle B F C is equal to the angle C G B; therefore the triangles are equal (by prop. 4th), and the remaining angles of the one to the remaining angles of the other; viz. the angle F B C to G C B, and the angle B C F to C B G: and since it has been demonstrated that the whole angle A B G is equal to the whole A C F, and that the angles C B G and B C F, which are parts of these, are also equal; the remaining angle A B C is therefore equal to the remaining angle A C B, which are the angles at the base of the triangle A B C: and it has also been proved, that the angle F B C is equal to the angle G C B, which are the angles upon the other side of the base. Q. E. D.

Corollary.—From the demonstration of this proposition it is evident, that every equilateral triangle is also equiangular; that is, it has all its angles equal to each other.

For all equilateral triangles are also isosceles triangles; but all isosceles triangles are not equilateral ones; therefore, when a triangle has only two of its sides equal, it has only two of its angles equal; but when it has all its sides equal it has also all its angles equal.

The intricacy of this proposition, and its being placed near the beginning of the Elements, has procured it the name of the *Pons Asinorum*, or Bridge of Asses. The difficulty in the demonstration arises from proving the angles upon the other side of the base equal to each other

* The letters Q. E. D. are used instead of the words *quod erat demonstrandum*, which was to be demonstrated.

MECHANICS.

The quantity of motion, or, as it is often termed, the *momentum* of a body, is measured by the velocity and quantity of matter jointly; that is, the quantity of matter in any body, multiplied by its velocity, is considered as its *momentum*, at least in comparing the quantity of motion in one body with that in another.

Thus, if the quantity of matter in one body be represented by the number 8, and its velocity by 3; and the quantity of matter in another body by 6, and its velocity by 4, the *momentum** or quantity of motion in each of these bodies is equal. For 8 multiplied by 3 is equal to 6 multiplied by 4.

The cause of motion is denominated *force*, and a force is always measured by its *effect*; that is, by the motion which it produces in a given time.

Forces are often represented by lines, as well as by numbers. lines are employed when the motions which they produce are in any particular direction, with respect to another line.

Forces have received different names according to the manner in which they act, as impact or percussion, gravity, pressure, &c.

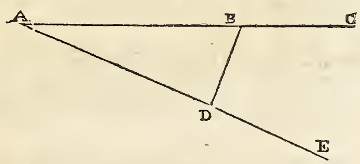
When a force produces its effect instantaneously, it is said to be *impulsive*, or to act by impulse.

When it acts incessantly, it is called *constant*, or a continued force.

Constant forces are of two kinds, *uniform* and *variable*. A force is said to be *uniform*, when it always produces equal effects in equal successive portions of time; and variable, when the effects produced in equal times are unequal.

As the velocity of a body is sometimes estimated in a direction different from that in which it actually moves, we shall here shew how its place may be determined at any time, in a direction making any given angle with the one in which it is actually moving.

Thus suppose a body to move along the line A C, and that when it has reached the point B, it is required to find its place in the line A E, which makes with A C a given angle.



This is done by drawing the lines B D from the body, or point B, at right angles, to the line A E, that is, by letting fall a perpendicular from the point B upon the line A E.

The *velocity* of a body moving in a given direction, is to its velocity estimated in any other direction, as radius to the cosine of the angle which the two directions make with one another: or the velocity of the body multiplied by the cosine of the angle which the directions make with each other, is the velocity of the body reduced to the direction of that line. And the *space* described by the body in its *own* path, multiplied by the cosine of the angle, is the *space* described by the perpendicular in the other line. Hence, if the velocity of the body in its own path be uniform, it will be uniform when reduced to any other direction.

As the performance of this operation requires a slight knowledge of trigonometry, we shall here illustrate it by an example.

Suppose a body to move in the direction A C, with a velocity of 50 feet per second, and that its velocity is required in the direction A E, which make with A C an angle of 30 degrees. The cosine of 30 degrees is ·866, which, multiplied by 50, is 43·3, the velocity per second in the direction A E.

Again, let the space passed over in the direction A C in any given time, be 500 feet, required the space passed over in the direction A E in the same time. Here ·866 multiplied by 500, is 433, the number of feet passed over in the direction A E.†

ON THE LAWS OF MOTION.

1st Law. *If a body be at rest, it will continue at rest; and if in motion, it will continue to move uniformly forward in a right line, if it be not disturbed by the action of some external cause.*

The truth of this law is perfectly evident, for if there be no action of another body, there can be nothing to determine it to move in one direction more than another when it is at rest; and if it be in motion, it must continue to go on in the same direction, if there be nothing to turn it out of that direction.

It is likewise impossible to change its velocity without some cause, for there is no tendency in matter itself either to increase or diminish any motion impressed upon it.‡

* The plural of this word is *momenta*.

† The cosine here employed is the *natural* cosine of the angle, radius or the sine of 90 degrees being unity, or—1. These are the sines generally alluded to in Works on Natural Philosophy; tables of natural sines are to be found in all the common works which contain mathematical tables.

‡ The resistance which a body makes to any change in its state, whether at rest or in a state of rectilineal motion, is called the *inertia*, or vis in ertia, as has already been remarked, at page 7.

The causes which retard a body in motion are, collision, gravity, friction, and the resistance of the air; and it will readily appear, by the following experiments, that when these causes are removed, or due allowance made for their known effects, we are necessarily led to infer the truth of the law stated above.

1st. If a ball be thrown along a rough pavement, its motion, on account of the many obstacles it meets with, will be very irregular, and soon cease; but if it be bowled upon a smooth bowling green, its motion will continue longer, and be more rectilineal: and if it be thrown along a smooth sheet of ice, it will preserve both its direction and its motion for a still longer time.

In these cases the gravity, which acts in a direction perpendicular to the plane of the horizon, neither accelerates nor retards the motion; the causes which produce the latter effect are collision, friction, and the air's resistance; and in proportion as the two former of these are lessened, the motion becomes more nearly uniform and rectilineal.

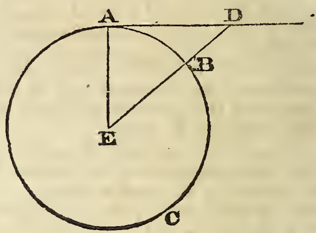
2nd. When a wheel is accurately constructed, and a rotatory motion about its axis communicated to it, if the axis, and the grooves in which it rests, be well polished, the motion will continue a considerable time; if the axis be placed upon friction wheels, the motion will continue longer; and if the apparatus be placed under the receiver of an air pump, and the air be exhausted, the motion will continue, without visible diminution, for a very long time.

In these instances, gravity, which acts equally on opposite points of the wheel, neither accelerates nor retards the motion; and the more care we take to remove the friction, and the resistance of the air, the less is the first motion diminished in a given time.

From these, and similar experiments, we are led to conclude, that all bodies in motion would uniformly persevere in that motion, were they not prevented by external impediments; and that every increase or diminution of velocity, every deviation from the line of dirction, is to be attributed to the agency of such causes.

It is in consequence of the tendency to persevere in rectilineal motion that a body revolving in a circle constantly endeavours to recede from the centre. The effort thus produced is called a *centrifugal force;* and as it arises from absolute motion only, whenever it is observed, we are convinced that the motion is real.

In order to see the nature and origin of this force, suppose a body to describe the circle A B C; then, at any point A, it is moving in the direction of the line A D,



and in this direction, by the first law of motion, it endeavours to proceed; also, since every point D in the line is without the circle, this tendency to move on in the direction of the line, is a tendency to recede from the centre of motion; and the body will actually fly off, unless it is prevented by an adequate force.

The following experiment is given by Sir I. Newton, to shew the effect of the centrifugal force, and to prove that it always accompanies an absolute circular motion.

Let a bucket, partly filled with water, be suspended by a string, and turned round till the string is considerably twisted; then let the string be suffered to untwist itself, and thus communicate a circular motion to the vessel. At first the water remains at rest, and its surface is smooth and undisturbed; but as it gradually acquires the motion of the bucket, the surface grows concave towards the centre, and the water ascends up the sides, thus endeavouring to recede from the axis of motion; and this effect is observed gradually to increase with the absolute velocity of the water, till at length the water and the bucket are relatively at rest. When this is the case, let the bucket be suddenly stopped, and the absolute motion of the water will be gradually diminished by the friction of the vessel; the concavity of the surface is also diminished by degrees, and at length, when the water is again at rest, the surface becomes plane. Thus we find, that the centrifugal force does not depend upon the relative, but upon the absolute motion, with which it always begins, increases, decreases, and disappears.

2nd Law. *The change of motion is always proportioned to the force impressed, and takes place in the direction in which the force acts.*

In order to understand the meaning and extent of this law of motion, it will be convenient to distinguish it into two cases, and to point out such facts, under each head, as tend to establish its truth.

1st. The same force, acting freely for a given time, will always produce the same effect, in the direction in which it acts.

Ex. 1. If a body, in one instance, fall perpendicularly through $16\frac{1}{12}$ feet in a second, and thus acquire a velocity which would carry it, uniformly, through $32\frac{1}{6}$ feet in that time, it will always, under the same circumstances, acquire the same velocity.

The effect is the same, whether the body begins to move from rest or not.

2d. If the force impressed be increased or diminished in any proportion, the motion communicated will be increased or diminished in the same proportion.

Ex. 2. If a body descend along an inclined plane, the length of which is twice as great as its height, the force which accelerates its motion is half as great as the force of gravity; and, allowing for the effect of friction, and the resistance of the air, the velocity generated in any time is half as great as it would have been, had the body fallen, for the same time, by the whole force of gravity.

In estimating the effect of any force, two circumstances are to be attended to; first, we must consider what force is actually impressed; for this alone can produce a change in the state of motion or quiescence of a body. Thus, the effect of a stream upon the floats of a water-wheel is not produced by the whole force of the stream, but by that part of it which arises from the excess of the velocity of the water above that of the wheel; and it is nothing, if they move with equal velocities. Secondly, we must consider in what direction the force acts; and take that part of it, only, which lies in the direction in which we are estimating the effect. Thus, the force of the wind actually impressed upon the sails of a windmill, is not wholly employed in producing the circular motion; and therefore in calculating its effect, in this respect, we must determine what part of the whole force acts in the direction of the motion.

3d Law. *The action and re-action of bodies on one another are equal.*

When motion is communicated by collision or impulse, the quantity of motion gained by the one body, in any direction, is just equal to that which is lost by the other in the same direction.

When motion is communicated without apparent contact, as in the case of gravitation, and what is ascribed to attraction or repulsion, the quantity of motion gained by the one body is just equal to that which is gained by the other, but in the opposite direction.

The first of these propositions includes in it the first law of motion, and when so understood, properly expresses the *inertia* of body which has already been so fully explained as to require no additional remarks in order to render it intelligible. The second proposition is only known to us by experience.

The first may be illustrated as follows: If two bodies are equal, and have equal velocities, it is evident that there must be an equilibrium, when they meet, or strike against each other. If the one be double the other, and have half the velocity of that other, an equilibrium will also take place when they meet; for the first may be divided into two parts, each of which would destroy half the velocity of the other; consequently the whole motion of the second would thus be destroyed. Hence it has been inferred, that bodies that have equal quantities of motion, have equal forces, or equal powers to produce motion.

This may be very easily and satisfactorily proved, as follows:

Take two equal and similar cylindrical pieces of wood, and from one of them let a small steel point project; suspend them by equal strings, and let one of them descend through any arc of a circle, and impinge or strike upon the other at rest; then by means of the steel point, the two bodies will move on together as one mass, and with a velocity equal to half the velocity of the body first put in motion. Thus the momentum, or quantity of motion, remains unaltered; or, as much motion has been gained by the body struck, as has been lost by the body striking it. The experiment may be varied by loading one of the bodies with lead, and observing the effect produced when the weight of the one body is any number of times that of the other. But in making experiments to establish this law of motion, allowance must be made for the resistance of the air; and care must be taken to obtain a proper measure of the velocity, both before and after the bodies strike each other.

The third law of motion is not confined to cases of actual impact; the effects of pressure and attraction, as already stated, are also equal, in opposite directions.

When two bodies sustain each other, the pressures in opposite directions must be equal, otherwise motion would ensue; and if motion be produced by the excess of pressure on one side, the case coincides with that of impact, the effects of which have just been described.

When one body attracts another, it is itself also equally attracted: and the momentum communicated to the one, will also be communicated to the other in the opposite direction. A loadstone and a piece of iron, equal in weight, and floating upon similar and equal pieces of cork, approach each other with equal velocities, and therefore with equal momenta; and when they meet, or are kept asunder by any obstacle, they sustain each other by equal and opposite pressures.

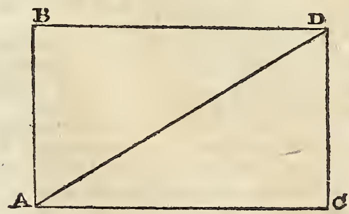
These laws are the simplest principles to which motion can be reduced, and upon them the whole theory depends. They are not, indeed, self-evident, nor do they admit of accurate proof by experiment, on account of the great nicety required in adjusting the instruments, and making the experiments; and on account of the effects of friction, and the air's resistance, which cannot entirely be removed. They are, however, constantly and invariably suggested to our senses, and they agree with experiment as far as experiment can go; and the more accurately the experiments are made, and the greater care we take to remove all those impediments which tend to render the conclusions erroneous, the more nearly do the experiments coincide with the laws.

COMPOSITION AND RESOLUTION OF FORCES.

It has already been stated at page 21, that the momenta of bodies may either be represented by numbers or lines; and that lines had the advantage of representing the direction, as well as the forces of the bodies in motion.

Two forces are said to be represented by two lines, when the motions which they singly produce are in the directions of those lines, and proportional to them.

Let a body A be acted on by two forces at the same instant, one of which acting alone, would cause it to move uniformly over A B in a given time; and the other acting alone, would cause it to move over A C, at right angles to A B, in the same time; then the body will describe the diagonal line A D, and at the end of the given time will have arrived at the point D;



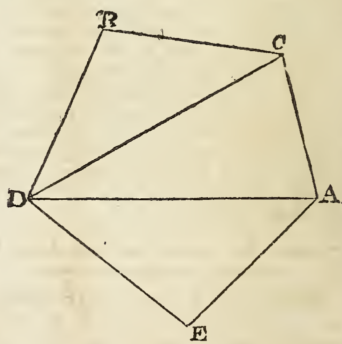
For the motion of the body in the one of these directions, will not be changed by the force impelling it in the other.

If the lines which each of two forces acting singly would have caused a body to describe in the same time, make any angle whatsoever with one another, the line which the body will describe in that time, when both the forces act on it at the same instant, is the diagonal of the parallelogram under the two first-mentioned lines *

Let A B and A C represent two forces acting upon a body A, and let the motions be communicated to the body at the same instant; and since A B and A C are the spaces described by the body in the same time, the line A D is equivalent to them both; and therefore the body will be found, at the end of the given time, to have arrived at the point D, as in the former case.

If two sides of a triangle, taken in order, represent the spaces over which two uniform motions would separately carry a body in a given time; when these motions are communicated at the same instant to the body, it will describe the *third* side uniformly in that time; for every triangle is half a parallelogram, the opposite sides of which being equal to each other, the diagonal must divide it into two equal parts; and it has been shown by the last figure, that when two forces act upon a body at the same time, with forces which would cause it singly to describe lines making any angle with each other, that the line the body will actually describe in that time, is the diagonal of the parallelogram under these two lines; but the diagonal is the third side of the triangle, therefore the truth of the proposition is manifest.

In the same manner, if the lines D B, B C, C A, and A E, taken in order, represent the spaces over which any uniform motions would, separately, carry a body in any given time,



these motions, when communicated at the same instant, will cause the body to describe the line D E, which completes the figure, in that time; and motion in this line will be uniform.

* A force is said to be equal or equivalent to any number of forces, when it will singly produce the same effect that the others produce jointly.

HYDROSTATICS.

THE following table exhibits the specific gravity of a great number of different substances, and will be found as accurate as any table of the same extent which has yet been presented to the public.

Distilled water, at the temperature of 55 degrees of Fahrenheit's thermometer, is assumed as the standard of comparison. A cubical foot of water at this temperature weighs nearly 62½ pounds avoirdupois, or 1000 avoirdupois ounces. Hence the specific gravity of water being assumed at 1000 in the table, the specific gravities of all the other bodies mentioned in the table will nearly express the real weight of a cubical foot of each, in avoirdupois ounces.

Table of the Specific Gravities of Bodies.

SOLIDS.

Platinum	21,470
Gold	19,300
Iridium	18,680
Tungsten	17,400
Mercury	13,600
Palladium	11,800
Lead	11,350
Wodanum	11,470
Rhodium	10,650
Silver	10,450
Bismuth	9,880
Uranium	9,000
Copper	8,900
Cabalt	8,600
Molybdenum	8,600
Nickel	8,400
Arsenic	8,350
Manganese	8,000
Iron	7,700
Tin	7,300
Zinc	6,900
Antimony	6,700
Tellurium	6,120
Chromium	5,900
Columbium	5,600
Selenium	4,300
Ruby, oriental	4,200
Garnet, Bohemian	4,188
Barium	4,000
Strontia	3,800
Diamond	3,517
White lead	3,160
Island crystal	2,720
Marble	2,707
Pebble stone	2,700
Coral	2,700
Jasper	2,666
Rock crystal	2,650
Pearl	2,630
Glass	2,600
Flint	2,570
Onyx stone	2,510
Common stone	2,500
Glauber salt	2,250
Crystal	2,210
Oyster shells	2,092
Brick	2,000
Earth	1,984
Nitre	1,900
Vitriol	1,880
Alabaster	1,874
Horn	1,840
Ivory	1,820
Brimstone	1,800
Chalk	1,793
Borax	1,717
Allum	1,714
Clay	1,712
Dry bone	1,660
Human calculus	1,542
Sand	1,520
Gum-arabic	1,400
Opium	1,350
Lignum-vitæ	1,327
Coal	1,250
Jet	1,238
Coral	1,210
Ebony	1,177
Pitch	1,150
Rosin	1,100
Mahogany	1,063
Amber	1,040
Brazil wood	1,031
Box wood	1,030
Common WATER	1,000
Bees wax	955
Butter	940
Logwood	913
Ice	908
Ash (dry)	838
Plumbtree (dry)	826
Elm (dry)	801
Oak (dry)	800
Yew	760
Crabtree	700
Beech (dry)	700
Walnut-tree (dry)	650
Cedar	613
Fir	580
Cork	238
New fallen snow	86

FLUIDS.

Quicksilver	14,000
Oil of vitriol	1,700
Oil of tartar	1,550
Honey	1,450
Spirit of nitre	1,315
Aqua fortis	1,300
Treacle	1,290
Aqua regia	1,234
Spirit of urine	1,120
Human blood	1,154
Sack	1,033
Urine	1,032
Milk	1,031
Sea water	1,030
Serum of human blood	1,030
Ale	1,028
Vinegar	1,026
Tar	1,015
WATER	1·
Distilled waters	993
Red wine	990
Linseed oil	932
Brandy	927
Oil of olive	913
Spirit of turpentine	874
Spirit of wine	866
Oil of turpentine	810
Common air	0,012

The specific gravities of the bodies contained in the foregoing table, and in all tables of this kind, can only be considered as the mean of a number of experiments made on each, and therefore cannot be considered as perfectly agreeing with the result of a single experiment, made for the purpose of determining the specific gravity of any particular substance; because the purity, the temperature, and several other causes, materially affect the result of an experiment of this kind.

The utility of accurate tables of this kind is very great; for, though the numbers in the table be only the relative weights of the bodies opposite to them, yet the real weight of a given bulk of any body may easily be determined from its specific gravity. An instance or two will render the method of doing this perfectly plain. It has been remarked above, that the number opposite to any substance in the table, not only expresses its *specific gravity*, but the real *weight* of a cubical foot of that substance in ounces avoirdupois; therefore to find the weight of any given number of cubical feet of any substance, it is only necessary to multiply the number of cubical feet by the number in the table opposite to the substance, and the product will be its weight in avoirdupois ounces.

Example: What is the weight of three cubical feet of lead?—The specific gravity of lead is 11·350, which multiplied by 3 is 34·050 ounces, or 2128 pounds 2 ounces avoirdupois.

If the given bulk be expressed in cubic inches, multiply the specific gravity by the number of cubic inches, and by the number 253·175 (which is the weight of a cubic inch of water, in grains, of the above temperature), and the product will be the weight in troy grains.

Example: Required the weight of 10 cubic inches of iron?—The specific gravity of iron is 7·700, which multiplied by 10 is 77·000, and this multiplied by 253·175, is 19·494·475 grains; which divided by 7000 (the number of grains in a pound avoirdupois) quotes 2 pounds 12 ounces 9 drams nearly, for the weight of the 10 cubical inches.

Another useful problem may be performed by this table; namely, to find the bulk of any substance when its weight is known. This is done by dividing the weight in ounces by the specific gravity in the table, the quotient is the bulk in cubic feet: if the quotient should not amount to a cubic foot, or if the answer be wanted in cubic inches, the quotient must be multiplied by 1728, the number of cubic inches in a cubic foot.

Example: required the bulk of 42 ounces of nickel? Here 42 divided by 8·400, the specific gravity of nickel, quotes ·005, or the 200th part of a cubic foot, which multiplied by 1728, gives $8\frac{16}{25}$ cubic inches for the bulk of 42 ounces of nickel.

By a slight attention to the foregoing examples, it will be perceived, that if the weight and bulk of any substance be known, its specific gravity may be found, for this is only to divide the weight by the bulk of the body expressed in cubic feet. Thus, suppose a piece of marble to contain 4 cubic feet, and that its weight is 604 lbs, or 9664 ounces; required the specific gravity of marbles?

The weight, 9664 ounces, divided by 4, the number of cubic feet, quotes 2,416, the specific gravity required.

SOLID BODIES FLOATING ON FLUIDS.

A solid floating on a fluid specifically heavier than itself, will be in equilibrio, or will rest, when it has sunk so far, that the weight of the fluid displaced is equal to the weight of the whole solid, and when the centres of gravity of the whole solid, and of the part immersed are in the same vertical line.

Hence, every solid, specifically lighter than a fluid which has an axis that divides it into two similar and equal parts, when placed in a fluid with its axis vertical, may sink to a position in which it will remain in equilibrio; that is, without turning either to the one side or the other.*

In such bodies there are always two opposite positions of equilibrium; but there is only one of them in which the body can float permanently.

When the equilibrium of a floating body is disturbed, or when the centres of gravity of the whole, and the part immersed are not in the same vertical line, the body will revolve on its axis, till it come into the position where these two points are in the same vertical line.

There are some bodies that in every position these two points are in the same vertical line. A homogeneous sphere, or globe, is a body of this kind: and so is a cylinder floating with its axis horizontal. These bodies have no tendency to maintain one position more than another; and their equilibrium, or floating position, is called the *equilibrium of indifference*.

Some floating bodies, when their equilibrium is disturbed, return to their steady position after a few oscillations backwards and forwards. Others, when ever so little disturbed, do not resume their former position, but turn on their centres of gravity, till they come into another position, when they are again in equilibrio. In the first case the equilibrium is said to be stable, in the latter case to be unstable, and then the body is said to *overset*.

When a floating body is made to revolve from the position of equilibrium, if the line of support (that is the vertical line passing through the centre of gravity of the immersed part) move so as to be on the same side of the line of pressure, (or the verticle passing through the centre of gravity of

* The centre of gravity of any body is that point upon which the body, when acted upon only by the force of gravity, will balance itself in all positions. This will be more fully explained when treating Mechanics in a future number.

the whole) with the depressed part, the equilibrium is *stable*, and the body will resume its former position. But if the line of support is on the same side of the line of pressure with the elevated part, the equilibrium is *unstable*, and the body will overset.*

When a floating body revolves about a given axis, the positions of equilibrium through which it passes are alternately those of stability and instability: for between a state in which a body has a tendency to remain, and another in which it has also a tendency to remain, as these tendencies are opposite to one another, there must be an intermediate position in which the tendency to remain is equal to nothing, or the body will revolve on its axis.

If the form and size of a body, floating in a fluid, be known, and its altitude above the surface, and the specific gravity of the fluid be also known, its stability may be calculated; but as the calculation could only be understood by a small portion of that class of readers for whom our publication is chiefly designed, we have declined to insert it here.†

ASTRONOMY.

HISTORY OF ASTRONOMY.

[*Continued from page* 16.]

Meton and Euctemon, two Greek astronomers, accordingly applied themselves to the study of this subject with great industry; and by sagaciously combining all the observations then known, formed a lunisolar period, or cycle of 19 years. This cycle was adopted on the 16th July, in the year 433 B. C. and is still in use. It is called the Metonic cycle, after the inventor of it. In this discovery is visible very extensive astronomical knowledge, and every appearance of great accuracy. Such was its success in Greece, that the order of the period was engraved in letters of gold, and at this period goes by the name of the Golden Number.

Among the ancients, Eudoxus is particularly distinguished for his knowledge, and also for his attention to Astronomy. He built an observatory at Cnidus, his birth-place, which was shown long after his death. He invented a sphere, (which is called Eudoxus' sphere,) to show the rising and setting of the sun and moon, &c. for the climate of Greece.

He also composed two books on Astronomy: the one was a description of the constellations, the other treated on the times of their rising and setting. Aratus, by order of Antiochus, king of Macedon, reduced all that was then known of Astronomy into Greek verse, anno B.C. 276. This poem is divided into two books, one of which describes the sphere of Eudoxus; the other gives rules for predicting the weather. Both of these have reached us entire.

While Astronomy made such great progress in Greece, it was cultivated also by some of the Western nations of Europe. Pytheas, a celebrated astronomer at Marseilles, observed in that city the meridian altitude of the sun, at the time of the summer solstice, by a gnomon for the purpose of determining the latitude of that place. This man travelled to other parts of the globe, for the purpose of observing the phenomena of nature. He mentions having visited an island, which he calls Thule, where the sun rose presently after he had set. As this is the case in Norway and Iceland, it is inferred that he had reached these countries.

The same philosopher discovered that the Polar star is not precisely at the Pole itself. He likewise pointed out the connection of the tides with the motion of the moon.

Alexander the Great, by his conquests, rendered great service, both to Astronomy and Natural Philosophy. On these subjects, Aristotle wrote, by his order, a great number of books. In one of these, entitled *De Cœlo*, he proves the spherical shape of the earth, from the circular shadow it casts on the moon in eclipses, and also from the difference of altitude observable on any of the fixed stars, in travelling north or south. He wrote one called *De Mundo*, which gives an account of the three quarters of the globe then known; viz. Asia, Africa, and Europe.

From this time Geography gradually became (through its alliance with Astronomy) a real science.

Horace mentions that the earth had been measured before his time; for he calls Archytas, who had been Plato's master, the measurer of the earth.

But the first person who measured the earth by a method consistent with the principles of Geometry and Astronomy, was Eratosthenes, librarian of the Alexandrian Museum. As this measurement was performed in a somewhat curious manner, it may be gratifying to the reader here to mention it, as it will serve to give some idea how that has lately been performed in Europe.

* By the centre of gravity of the immersed part is always meant its centre of gravity, supposing it homogeneous. In fact, it is the centre of gravity of the water displaced by the floating body.

† Those who wish to see this subject treated fully, may consult Dr. Young's Analysis of the Principles of Natural Philosophy.

Eratosthenes was informed, that, on the day of the summer solstice, the sun was vertical at noon to the city of Syene, on the borders of Ethiopia, under the tropic of Cancer. A well is particularly mentioned to have been illuminated to the bottom by the sun at noon on the solstitial day. He knew likewise that Alexandria and Syene were both under the same meridian.

From these data, by means of a concave hemisphere, with a stile fixed in its centre, he found that the shadow of the meridian sun caused by the stile at Alexandria, was one-fiftieth part of the whole circumference. Hence he inferred, that the arc of the heavens comprised between Alexandria and Syene must be the same; and that the distance between the two cities must likewise be a similar arc, or one-fiftieth part of the circumference of the earth. On measuring this distance, he found it to be 5000 stadia, which gave 250,000 stadia for the circumference of the earth. As there were different stadia then in use, it is not well ascertained how many feet a stadium contained. If it was the Egyptian stadium that was used, this measurement exceeds the modern measures about a sixth part.

About the same time with Eratosthenes, flourished Aristarchus of Samos, who has given a very simple method of determining the ratio of the distance of the sun and moon from the earth, which, though not very accurate, is yet ingenious.

Of all the ancient astronomers, no one has so much enriched the science, or acquired so great a name, as Hipparchus, a native of Nice in Bithynia, 142 B. C.

One of his first cares was to rectify the year, which before his time was made to consist of 365 days six hours, which he found to be a little too much. He also found that the sun was longer in traversing the six northern signs of the ecliptic than the other half of it; and deduced from this the eccentricity of the solar orbit.

He likewise made similar remarks and calculations for the lunar orbit.

From these data, he constructed tables of the motions of the sun and moon, which are the first of the kind that are mentioned.

Hipparchus made another important discovery. He found that the stars always preserved the same relative positions with respect to each other; but that they had all a trifling motion in the order of the signs of the zodiac, which was about 48″ in a year. He also substituted a more complete mode of measuring the ratio of the distance of the sun and moon from the earth, than the one given by Aristarchus. He made use chiefly of parallaxes; which is the method now in use. On the disappearance of a very large star, he set about numbering the stars, and to note down their configurations, respective distances, &c. and gave a very good catalogue of them.

This immense labour laid the foundation on which the whole superstructure of astronomy was to be raised. He was admired and celebrated in all nations where learning was pursued. Hipparchus was the first who applied this science to familiar purposes of the greatest utility in geography, by determining the situation of places by their latitudes and longitudes.

Cleomedes, who lived a little later than Hipparchus, has left a work on the sphere, the periods of the planets, their distances and magnitudes, with an account of ancient eclipses, which he says he derived the knowledge of from Pythagoras, Eratosthenes, and Hipparchus. This work is valuable, as it is the most ancient that has reached us on these subjects.

The next person that claims particular notice, was Julius Cæsar, who rendered an important service to the science of Astronomy, by new-modelling the Roman calendar, B.C. 46 years.

Cæsar appears to have been well versed in Astronomy. He discovered that Autumn occupied the place of the winter months of the calendar, and that winter occurred in the months of spring. He invited the astronomer Sosigenes from Athens to Rome to assist him in correcting this disorder. They began by giving fourteen months to the year of Rome, to re-establish the order of the seasons. They likewise determined that the year should consist of 365 days six hours in future; but, as we shall afterwards see, this was making the year too long by 11′ 11″; yet this was coming wonderfully near the real length of the tropical year, considering the state of science at that time. This is still called the Julian year, out of compliment to Julius Cæsar.

Menelaus, a learned geometrician, A.D. 55, also distinguished himself in astronomy, by the discovery of the principal theorems of spherical trigonometry, which are applicable to the purposes of Astronomy.

Astronomy had begun to languish in the school of Alexandria, when the celebrated Ptolemy made his appearance, in A.D. 140.

He was a native of Pelusium in Egypt, and, when very young, came to Alexandria to study in that school. His principal work is entitled the *Almagest*, an Arabic word which signifies the *great collection*. It contains all the ancient observations and theories, to which his *own* researches are added, and is considered as the most complete collection of ancient Astronomy that ever appeared.

Ptolemy embraced the common opinion,

that the sun, moon and planets moved round the earth as their common centre. This system continued to maintain its ground till the time of Copernicus, and has descended from Ptolemy to the present day, under the name of the Ptolemaic System.

Besides the Almagest, there exists another great work of Ptolemy's, his Geography, in which he determines the situation of places by their latitude and longitude, according to the method of Hipparchus. Ptolemy had the ambition, like Archimedes, to transmit the remembrance of his labours to posterity by a public monument. In the temple of Serapis, at Canopus, there is an inscription on marble, in which are explained the hypothesis of his astronomical system, such as the length of the year, the motions of the planets, &c. If there have been men of greater genius than Ptolemy, there is no man that ever collected a greater body of profound knowledge, or more truly conduced to the progress of Astronomy, considering the age he lived in, and the time he wrote.

From Ptolemy to the time of the Arabs, no astronomer of the first order is to be found among the Greeks, except, perhaps, Theon of Alexandria, who wrote a learned commentary on the Almagest, about the year 395.

Among the Arabs there have been many excellent astronomers. As there was no science to which they devoted so much attention, there were none in which they made so many discoveries. Their Caliphs were particularly distinguished for their knowledge and patronage of this science. They soon found that Ptolemy had stated the obliquity of the ecliptic a little too great; and, after many observations, found it to be nearly what it is at present.

The Caliph Almansor the Victorious, who ascended the throne in 754, ranks among the first of their astronomers. Haroun, his grandson, who reigned from 786 to 809, sent a present to Charlemagne of a water clock, in the dial of which were twelve small doors, forming the division of the hours. Each of these doors opened at the hour it marked, and let out little balls, which, falling on a bell of brass, struck the hours. The doors continued open till 12 o'clock, when 12 little knights, mounted on horseback, came out together, paraded round the dial, and shut all the doors. This clock at that time astonished all Europe.

After Haroun, his son Al Maimon succeeded to the throne. He also cultivated the study of Astronomy. In his time there lived several celebrated astronomers; among whom was Alfragan, who composed several books on astronomy; and from his facility in calculation, he was surnamed the Calculator.

Albategni was also among the greatest of the Arabian astronomers. He found the year to contain only two minutes less than what it was found to be by Dr. Halley 600 years after.

After the Arabs had conquered the greater part of Spain, in the year 1020, they built there many observatories to conduct their observations. Alhazen, one of their astronomers, has left a treatise on Optics, which contains the first established theory of refraction and twilight which we have.

Among the Persians, also, there have been many eminent astronomers. They made many observations to discover the real length of the solar year, which they fixed at 365 days, six hours. One of their chief astronomers was the famous Ulugh Beg, grandson of Tamerlane; he not only encouraged the sciences as a sovereign, but was himself reckoned one of the most learned men of his age. To determine the latitude of Samarcand, it is said he employed a quadrant, the radius of which was 180 feet!* He composed a catalogue of the stars, and several astronomical tables, the most perfect then known in the east. He was assassinated by his own son.

From the year 800 till the beginning of the fourteenth century, almost all Europe was immersed in gross ignorance. The only people who paid any regard to science, was the Arabs that settled in Spain, some of whom have been mentioned above. Profiting by the books they had preserved from the wreck of the Alexandrian library, they cultivated and improved *all* the sciences, and particularly Astronomy, in which they had many able professors.

From the beginning of the ninth century to the year 1423, when Purbachius appeared, there is no name that deserves to be mentioned as contributing to the improvement of Astronomy. Purbachius was a man of great talents; he began an Epitome of Ptolemy's Almagest; but died before it was completed. This was executed by his friend and pupil, John Muller, commonly called Regiomontanus. This man made many observations, and collected the writings of many of the ancient astronomers. He published ephemerides for thirty years to come, wrote a theory of the planets and comets, and calculated a table of sines and tangents for every degree and minute of the quadrant. He died in the year 1476.

Nicolas Copernicus, born 1473, rose next and made so great a figure in Astronomy, that the true system, discovered, or rather renewed by him, has been ever

* It is thought by many astronomers, that this must have been a gnomen instead of a quadrant.

since called the Copernican System. He restored the old system of Astronomy taught by Pythagoras, which had been set aside from the time of Ptolemy. His understanding at once revolted against the explanations which that philosopher had given of the motions of our planetary system; and set about correcting his mistakes, by laying the foundation of what is at this day held to be the true system of the world. This system he gradually improved by a long series of observations, and a close attention to the writings of ancient authors. His first grand work was printed in 1543, under the care of Schoner and Osiander; and he received a copy of it only a few hours before his death, on the 23d May 1543, at the age of seventy years.

After the death of this great man, there were several astronomers of considerable note, that greatly improved the science; but the only one that claims particular notice was Tycho Brahe, a Danish nobleman, who was the inventor of a new system, a kind of semi-Ptolemaic, which he vainly endeavoured to establish instead of the Copernican. His numerous works shew that he was a man of great abilities; and it is to be regretted that he sacrificed his talents, and perhaps his inward conviction, to superstitious considerations. He restored the earth to its fancied immobility, and made the sun and moon revolve round it; but the planets he made to revolve round the sun, which was a still more absurd hypothesis than that of Ptolemy. But we ought to forgive this error, or rather weakness, in return for the many observations and discoveries with which he enriched Astronomy. No man ever made more observations than Tycho Brahe.

Contemporary with Tycho flourished several eminent astronomers, among whom was the famous Kepler. To him we owe the true figure of the orbits of the planets, and the proportions of the motions and distances of the various bodies which compose the solar system. The three great Laws of Kepler may be said to be the foundation of all Astronomy. Kepler was born in 1571, and died in 1631.

Galileo was the next person who rendered any very important services to Astronomy. He was the first who applied the telescope to astronomical observations, and with it made many useful and valuable discoveries. By the observations and reasoning of Galileo, the system of Copernicus acquired a probability almost equivalent to demonstration. By espousing the opinions of Copernicus, he drew on him the vengeance of the Inquisition, who decreed that he should pass his days in a dungeon; but he was liberated after the expiration of a year, on condition that he should never more teach or hold up the Copernican as the true system of Astronomy. He was born in the year 1564, and died in 1642.

In spite of the Inquisition, or the passages in Scripture which were always brought forward as objections to the motion of the earth, the system of Copernicus gained ground every day.

Contemporary with Galileo were a number of astronomers, who contributed to the progress of the science. Baron Napier published his tables of logarithms in 1614. Bayer also, obtaining great celebrity by the publication of his *Uranometria*, in which the stars were designated by the letters of the Greek alphabet, which is still the case on our celestial globes and planispheres.

Gassendi, a French philosopher, saw the planet Mercury on the sun's disc, which was the first observation of the kind. A little after this, in the year 1633, Mr Horrox, an Englishman of very extraordinary talents, discovered that Venus would pass over the disc of the sun on the 24th November, 1639. This event he only mentioned to one friend, a Mr. Crabtree; and these two men were the only persons in the world who observed this transit, which was the first transit of Venus that had ever been viewed by human eyes. Mr. Horrox made many useful observations about this time, and had even formed a new theory of the moon, so ingenious as to attract the attention of Sir Isaac Newton. But the hopes of astronomers, from the abilities of this extraordinary young man, were soon blasted, for he died in the beginning of the year 1640, aged twenty-four years.

Hevelius, burgomaster of Dantzic, also rendered himself eminent by his numerous and delicate observations. He founded an observatory at Dantzic, and furnished it with a great many excellent instruments, some of which were divided into so small divisions as 5″. His observations on the spots of the sun, and on the nature of comets, were very numerous; and his catalogue of fixed stars, containing the longitude of above 1888, was remarkable for its accuracy. It is to him also we are indebted for the first accurate description of the spots on the moon.

The improvement of the telescope continued to lay open new sources of discovery. The celebrated Huygens constructed two excellent telescopes, one of twelve feet in length, and the other twenty-four, with which he discovered the fourth satellite of Saturn; which he said afterwards led him to discover the *ring* that surrounds that planet. Huygens was likewise the first person who applied pendulums to clocks. He died in 1695, aged 66 years.

[*To be continued.*]

Miscellaneous Subjects.

LIFE OF ARCHIMEDES.

Archimedes was born at Syracuse, and related to Hiero, King of Sicily: he was remarkable for his extraordinary application to mathematical studies, but more so for his skill and surprising inventions in Mechanics. He excelled likewise in Hydrostatics, Astronomy, Optics, and almost every other science; he exhibited the motions of the heavenly bodies in a pleasing and instructive manner, within a sphere of glass of his own contrivance and workmanship; he likewise contrived curious and powerful machines and engines for raising weights, hurling stones, darts, &c. launching ships, and for exhausting the water out of them, draining marshes, &c. When the Roman Consul, Marcellus, besieged Syracuse, the machines of Archimedes were employed: these showered upon the enemy a cloud of destructive darts, and stones of vast weight and in great quantities; their ships were lifted into the air by his cranes, levers, hooks, &c. and dashed against the rocks, or precipitated to the bottom of the sea; nor could they find safety in retreat; his powerful burning glasses reflected the condensed rays of the sun upon them with such effect, that many of them were burned. Syracuse was however at last taken by storm, and Archimedes, too deeply engaged in some geometrical speculations to be conscious of what had happened, was slain by a Roman soldier. Marcellus was grieved at his death, which happened A. C. 210, and took care of his funeral. Cicero, when he was Questor of Sicily, discovered the tomb of Archimedes overgrown with bushes and weeds, having the sphere and cylinder engraved on it, with an inscription which time had rendered illegible.

His reply to Hiero, who was one day admiring and praising his machines, can be regarded only as an empty boast: "Give me," said the exulting philosopher, "a place to stand on, and I will lift the earth." This however may be easily proved to be impossible; for, granting him a place, with the simplest machine, it would require a man to move swifter than a cannon shot during the space of 100 years, to lift the earth only *one inch* in all that time.—Hiero ordered a golden crown to be made, but suspecting that the artists had purloined some of the gold and substituted base metal in its stead, he employed our philosopher to detect the cheat; Archimedes tried for some time in vain, but one day as he went into the bath, he observed that his body excluded just as much water as was equal to its bulk; the thought immediately struck him that this discovery had furnished ample data for solving his difficulty; upon which he leaped out of the bath, and ran through the streets homewards, crying out, *I have found it! I have found it!*—The best edition of his works is that of Torelli, edited at the Clarendon Press, Oxford, fol. 1792, by Dr. Robertson, Savilian Professor of Astronomy.

Longitude Scale; or, Lunar Corrector.
By Captain Thomson.

There is, perhaps, no problem in the whole circle of the physical science of more practical utility, nor one which has more engaged the attention of mathematicians, than that of determining the longitude of a ship at sea. The difficulty of solving this problem, however, does not consist in any deficiency in the theory, but in the mechanical, or practical part of the operation; for it is well known that the difference of longitude between any two places, is merely the difference between the times at those places converted into degrees, at the rate of fifteen degrees to an hour. Now various plans have been devised for ascertaining this difference; but to put those plans in practice is found to be attended with considerable trouble and difficulty. The most obvious, and perhaps the most easy, method of discovering the difference of longitude between any two places, is to have a watch, or *chronometer*, well regulated according to the time at one of the places, and then to carry it to the other; where, on being compared with the time as reckoned there it will give the difference of longitude. This is what is often done on board of ship. These chronometers are regulated to the time at Greenwich previous to sailing; and were they to go regularly, and exhibit the Greenwich time accurately, would afford a simple and correct method of ascertaining the longitude of any place to which they might be transferred, whenever the time was determined at that place. But it is well known that chronometers often change their rate, at sea, from various causes; it therefore becomes necessary not only to have some means of correcting them, but of ascertaining the longitude of a ship independently of these instruments. Now the means of accomplishing this desirable object with great accuracy is afforded by the celestial bodies, together with the *Nautical Ephemeris;* for if the distance between the sun and the moon, or the moon and a star, be accurately measured with a sextant, the longitude of the place of observation can be determined very correctly; but this requires rather a long and tedious calculation, even by the shortest and easiest method which has yet been devised. Captain Thomson has, however, invented a sliding scale, which greatly shortens and simplifies the process. The fact is, that by means of his scale no calculation whatever is necessary to reduce the apparent to the true distance; and any person who can take the distance between the sun and the moon, will find no difficulty in reducing it to the *true* distance, by means of the lunar scale. This operation may be performed in less than two minutes: and the result will generally be within two or three seconds of that obtained by the most rigid calculation.

One side of the scale is appropriated to the purpose we have just stated; and the other to deducing the time from the altitude of a celestial body: which will always come out exceedingly near to what would be obtained by the common method of calculation.

It is scarcely possible, in an article like the present, either to give an adequate description of the scale itself, or the manner of using it; but both appear to us to be simple, and we are convinced that it will be found exceedingly useful at sea. We ought also to state, that the scale is accompanied by a very neatly printed book of instructions, and several tables, which are indispensibly necessary to the practical navigator.

We are happy to see that this excellent instrument has met with the approbation of some of the best judges of such instruments that are to be found in London.

ON AQUATINTA ENGRAVING.

To the Editor of the Artisan.

Sir,—If the following short account of the method of effecting aquatinta engraving is thought worthy of a place in your valuable publication, it is at your service.

After the intended figure is outlined, by etching or otherwise, the plate is covered all over with a ground of resin, burgundy pitch, or mastic, dissolved in rectified spirits of wine; this is done by holding the plate in an inclined position, and pouring the above composition over it. The spirit of wine almost immediately evaporates, and leaves the resinous substance in a granulated state, equally dissolved over every part. The granulations thus produced, if examined through a magnifying-glass, will be found extremely regular and beautiful. When the particles are extremely minute, and near to each other, the impression from the plate appears to the naked eye exactly like a wash of Indian ink; but when they are larger, the granulations appear more distinct. This powder, or granulation, is called the aquatinta grain. The plate is next heated to make the powder adhere; and in those parts where a very strong shade is wanted, it is scraped away; but where strong lights are wanted, a varnish is applied. The aqua fortis, properly diluted with water, is then put on with a piece of wax, as in common etching or engraving; and by repeated applications of this process, scraping where darker shades are required, and covering the light parts with varnish, the final effect is produced.

Engraving by aquatinta was invented by Le Prince, a French artist, by whom the process was long kept secret. It is even said, that for some time he sold his prints (which are still reckoned excellent specimens), for drawings.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

Sir,—Having carefully examined the first number of your work, I am convinced it must be highly useful to all those who wish to become acquainted with the physical sciences, if continued upon the plan you propose in the Introduction. As I perceive by that part of your work that you mean to devote a portion of each number to subjects of a miscellaneous nature, I have taken the liberty to inclose two mathematical questions, which some of your ingenious readers may send you a solution, if you think them deserving of a place in the Artisan.—I am, Sir, &c.

Peter Plus.

1st. There is a lever, at the end of which is suspended a weight of 45 pounds, and at the other end a power of 2 lbs.: the greater weight is one foot from the *fulcrum*; and each foot in length of the leaver is one pound in weight: required the distance of the lesser weight from the fulcrum, to keep the greater weight in equilibrium?

2d. If a heavy sphere, whose diameter is 4 inches, be put into a conical glass, full of water, whose depth is 6 inches, and diameter 5 inches, how many cubical inches of water will run over?

PHILOSOPHICAL QUERY.

To the Editor of the Artisan.

Sir,—Having often heard it affirmed, that a boat passes more easily over *deep* water than *shallow*, and that a boatman can row his boat much quicker over deep than shoal water, I would be obliged to you, or any of your intelligent readers, to inform me if this is really the case; and, if it is so, what is the cause of so singular a fact.—I am, Sir, &c.

Mercator.

PNEUMATICS.

If the sole cause of the diminution of the temperature of the air, in ascending from the Earth's surface, were the distance from the Earth; and if it were admitted, that there is no current of air perpendicularly upwards, as there certainly is not, the diminution of temperature would follow the inverse ratio of the distance from the centre of the Earth, or the greater the distance from the Earth, the less would be the temperature.

Professor Leslie, of Edinburgh, has given a formula for determining the temperature of any *stratum* of air, or its temperature at any altitude, when the height of the mercury in the barometer is given. This formula we shall here state in words, and then give an example of its application. Divide the height of the column of mercury in the barometer, at the upper station, by its height at the lower station; divide also its height at the lower station by its height at the upper station, and subtract the former quotient from the latter, then multiply the remainder by the number 25, and the product is the diminution of temperature at the upper station in degrees of the *centigrade* thermometer, which may be converted into degrees of Fahrenheit's scale, by multiplying by 9 and dividing by 5.

For example:—Suppose the mercury in the barometer to stand at 30·1 inches at the bottom of a mountain, but at its top the mercury stood only at 26·4 inches: required the diminution of temperature between the two stations? Here 26·4 divided by 30·1, quotes ·88 nearly; and 30·1 divided by 26·4, quotes 1·14, from which ·88 being subtracted, leaves ·26, and this multiplied by 25, gives $6\frac{1}{2}$ nearly, for the diminution of temperature in degrees of the centigrade scale, which are equal to 11·7 degrees of Fahrenheit's scale.

The fact, that the mercury in the barometer sinks on ascending into the atmosphere, was first suggested by Pascal, and ascertained by experiments made under his direction. This important fact was soon afterwards applied to the measurement of heights, in France, by Mariotte, and in England by Halley. The method of accomplishing this, however, remained very imperfect, till De Luc applied the corrections for the difference of temperature, and directed simultaneous observations to be made at the upper and lower station. He fell into some errors, which were afterwards pointed out and corrected by Trembley, Sir George Shuckburgh, and General Roy. La Place has more recently made barometrical measurement the subject of his researches, but though the formula he has given is more simple than most others, yet we consider it too complicated and algebraical to be inserted here; we shall therefore present our readers with a rule deduced by the ingenious professor Leslie, for determining the height of mountains, &c. which is unquestionably the simplest that has yet been given, and sufficiently accurate for any purpose to which that instrument may be applied.

The rule is this:—*As the sum of the columns of mercury, in the barometer, at the upper and lower stations, is to their difference, so is the constant number* 52,000, *to the approximate height.**

Two corrections, depending on the variation of temperature, at the upper and lower stations are besides required.

The first of these is for the expansion of the mercury in the barometer at the upper station, and is obtained thus:—Multiply the $\frac{1}{10,000}$ part of the column at the upper station by twice the difference of the attached thermometers, and add the product to the upper column. This correction is, however, so trifling on small heights, that it may be entirely neglected. But the following correction is of much more importance. It becomes necessary, on account of the expansion of the air by heat, and is obtained by multiplying the $\frac{1}{1000}$ part of the approximate height by twice the sum of the degrees of the detached thermometers. This correction being added to the approximate height, gives the true height.†

In order to render the method of performing this operation as plain as possible, we shall here give an example of its application. Suppose the barometer to stand at 30·091 inches at the bottom of a mountain which is to be measured, the attached thermometer at $15^{\circ}\cdot7$, and the detached at $15^{\circ}\cdot6$, while on the top of the mountain the barometer stood at 26·409 inches, the attached thermometer at 10°, and the detached at $8^{\circ}\cdot8$. Required the height of the mountain.‡

Here twice the difference of the attached thermometers is $11^{\circ}\cdot4$, which multiplied into ·00264, the $\frac{1}{10,000}$ part of 26·409 gives ·03 for the correction of the upper barometer. Then the sum of 30·091 and 26·439 is 56·53; and their difference is 3·652; therefore, 56·53 : 3·652 : : 52·000 : 3359 the

* This number is the more easily remembered, from the division of the year into weeks.

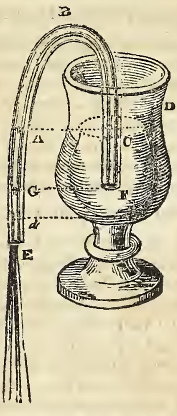
† In measuring heights by the barometer, a *detached* thermometer is used along with the one attached to the barometer, in order to ascertain the temperature of the air with exactness. The centigrade thermometer is the one supposed to be used in this rule.

‡ The character (°) signifies degrees.

approximate height in feet And twice the sum of the degrees marked on the detached thermometer is 48·8, which multiplied into 3·359, the $\frac{1}{1000}$ part of the approximate height gives 164; this added to the approximate height, gives 3,533 feet for the true height.

AIR AS ACCELERATING OR RETARDING MOTION.

Having already stated, at page 11, that if the end of a tube be immersed in water, and the air extracted from the tube, the water will ascend in the tube to the height of 33 feet; we have now to remark, that if the tube be bent in the form of the one A B C in the following figure,



the water will flow through the tube in a continued stream, provided the height from the surface of the water, to the top of the bending does not exceed the height stated above (33 feet).

A tube bent in this shape is called a *syphon.* If the syphon, instead of having the air extracted by suction, be filled with water, and the ends stopped till it be inverted, with the shorter leg immersed in water, the same effect will follow.

The cause of the water descending is its greater weight in the longer leg of the tube, and the pressure of the air on the surface of the water continues the supply.

The syphon may be employed to raise water over a height less than 33 feet, if it is to descend below the level of the fountain on the opposite side. It could not, however, be conveniently employed if the height was near to 33 feet; because the velocity with which the water in the shorter leg is made to ascend, depending on the difference between that height and 33 feet, the length of the column which the air is just able to sustain, might not afford a sufficient supply for the stream descending in the longer leg.

Te syphon is properly a *pneumatico-hydraulic* machine, the action of water and of air being both necessary to its effect. It is, however, the simplest of all the instruments employed for raising water. But it is now more generally employed for decanting liquors, or in transferring them from one vessel to another, when they are to be removed to a vessel lower than the one that contains them.

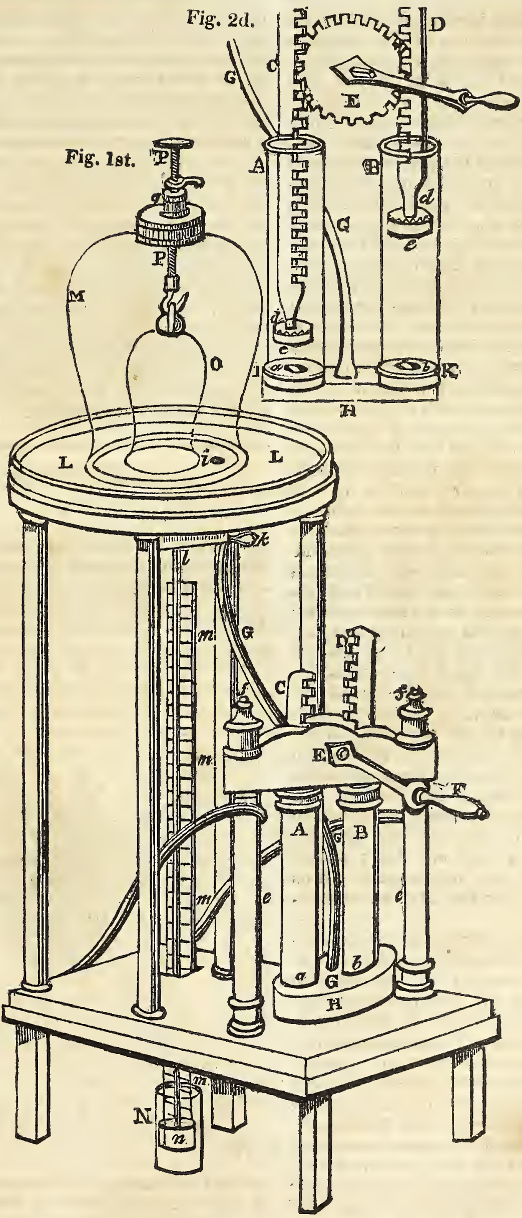
The *Air Pump* is a machine by which the air is extracted from close vessels. It was invented about the year 1654, by Otto Guericke, a native of Magdeburgh, in Germany, and marks an important era in the history of the physical sciences. It has, however, received great improvements since, by several men of genius, at different periods.

The air pump is in effect the same as the water pump, and whoever understands the one, will have little difficulty in understanding the other. We shall, however, present our readers with the figure of one of the most approved kind, and endeavour to give as clear and comprehensive a description of its several parts as possible, previous to stating some of the most important properties of the air which that instrument has been the means of making known to us.

Fig. 1st is the Air Pump complete, with a glass receiver upon the pump-plate. All receivers must be ground air-tight; that is, they must neither let *out* nor *in* any air at its edges, when placed on the pump-plate. If the receiver be not sufficiently well ground for this purpose, a piece of wet leather must be placed between the receiver aud the pump-plate. When this is done the receiver may be exhausted, or the air may be extracted from it by turning the handle F backwards and forwards till no more air can be forced out of it, which may be known by observing that the mercury ascends no higher in the tube *lmn*; and the receiver will then be held down to the plate by the pressure of the external air, or atmosphere. For, as the handle (see fig. 2d) is turned backwards, it raises the piston *de* in the barrel B K, by means of the wheel F and rack D *d*: and, as the piston is leathered so tight as to fit the barrel exactly, no air can get between the piston and barrel; and therefore, all the air above *d* in the barrel is lifted up towards B, and a vacuum is made in the barrel from *e* to *b*; upon which, part of the air in the receiver M (fig. 1), by its

Fig. 2d.

Fig. 1st.



spring, rushes through the hole *i*, in the brass plate L L, along the pipe G C G, which communicates with both barrels by the hollow trunk I H K (fig. 2), and pushing up the valve *b*, enters into the vacant place *b c* of the barrel B K. For, wherever the resistance or pressure is taken off, the air will run to that place, if it can find a passage. Then, as the handle F is turned toward, the piston *d e* will be depressed in the barrel; and, as the air which had got into the barrel cannot be pushed back through the valve *b*, it will ascend through a hole in the piston, and escape through the valve at *d*: and be prevented by that valve from returning into the barrel, when the piston is again raised. At the next raising of the piston, a vacuum is again made in the same manner as before, between *b* and *e*; upon which more of the air, which was left in the receiver M, gets out by its spring, and runs into the barrel B K, through the valve B. The same thing is to be understood with regard to the other barrel A I; and as the handle F is turned backwards and forwards, it alternately raises and depresses the pistons in their respective barrels; always raising one whilst it depresses the other. And, as there is a vacuum made in each barrel when its piston is raised, every particle of air in the receiver M pushes out another, by its spring or elasticity, through the hole *i*, and pipe G G, into the barrels, until at last the air in the receiver of the ordinary air-pump comes to be so much dilated, or rarefied, that it can no longer open the valves; and then no more can be taken out. Hence there is no such thing as making a perfect vacuum in the receiver; for the quantity of the air taken out at any one stroke, will always be as its density in the receiver. For it has been ascertained, that if the number of strokes of the piston increases in arithmetical progression, the quantity of air remaining in the receiver, and also its density, will form a series of terms decreasing in geometrical progression. Thus, if the receiver and barrels were of equal capacity, every stroke of the piston will diminish the quantity and density of the air *one half*; consequently there will be just as much left as was taken out at the last turn of the handle.

In air-pumps of the most improved construction, the valves are opened by a mechanical contrivance, so that the limit to the perfection of the instrument, arising from the spring of the air not being capable to open the valves, is now removed.

There is a screw *k* below the pump-plate, which being turned, lets the air into the receiver again, and then it becomes loose, and may be taken off the plate.

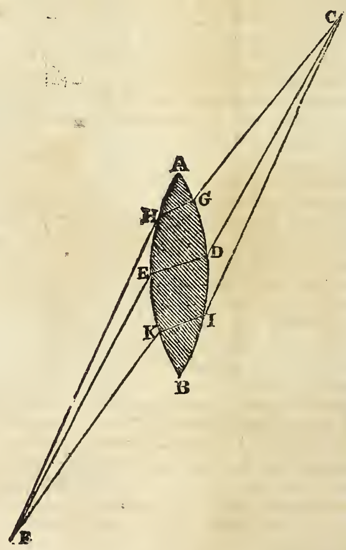
The two barrels of the pump are fixed to the frame E *e e* by two screw-nuts *f f*, which press down the top-piece E upon the barrels: and the hollow trunk H (fig. 2) is covered by a box, as G H in fig. 1.

There is a glass tube, *l m m n*, open at both ends, and about 34 inches long, attached to some pumps; the upper end communictaing with the hole in the pump-plate, and the lower end immersed in quicksilver at *n* in the vessel N. To this tube is fitted a wooden ruler *m m*, called the *gauge*, which is divided into inches and parts of an inch, from the bottom at *n*, (where it is even with the surface of the quicksilver), and continued up to the top, a little below *l*, to 30 or 31 inches.

As the air is pumped out of the receiver M, it is likewise pumped out of the glass tube, *l m n*, because that tube opens into the receiver through the pump-plate; and as the tube is gradually emptied of air, the quicksilver in the vessel N is forced up into the tube by the pressure of the atmosphere. And if the receiver could be perfectly exhausted of air, the quicksilver would stand as high in the tube as it does at that time in the barometer: for it is supported by the same power or weight (of the atmosphere) in both.

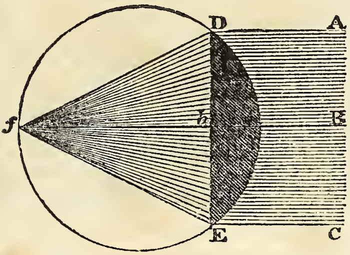
OPTICS.

A ray of light, C D, falling obliquely on the middle of a convex glass, as A B in the annexed figure,



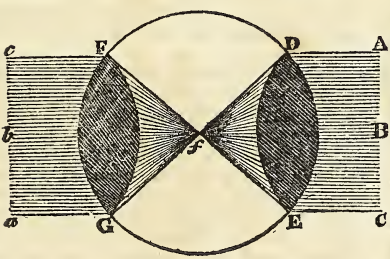
will go forward in the same direction D E, as if it had fallen with the same degree of obliquity on a plane glass; and will go out of the glass in the same direction with which it entered: for it will be equally refracted at the points D and E, as if it had passed through a plane surface. But the rays C G and C I will be so refracted, as to meet again at the point F. Therefore, all the rays which flow from the point C, so as to go through the glass, will meet again at F; and if they go farther onward, they cross at F, and go forward to the opposite sides of the middle ray C D E F, to what they were in approaching it in the directions H F and K E.

When parallel rays, as A B C, fall directly upon a plano-convex glass D E,



and pass through it, they will be so refracted, as to unite in a point *f* behind it; and this point is also called the principal focus; the distance of which, from the middle of the glass, is called the focal distance, which is equal to twice the radius, or the diameter, of the sphere of the glass's convexity.

When parallel rays, as A B C, fall directly upon a glass D E,



which is equally convex on both sides, and pass through it; they will be so refracted, as to meet in a point or principal focus *f*, whose distance is equal to the radius or semidiameter of the sphere of the glass's convexity. But if a glass be more convex on one side than on the other, the rule for finding the focal distance is this:—as the sum of the semidiameters of both convexities is to the semidiameter of either, so is double the semidiameter of the other to the distance of the focus; or, divide the double product of the radii by their sum, and the quotient will be the distance sought. Thus, suppose the radius of convexity of one side of a glass to be 6 inches, and the other 3 inches; the product of these numbers is 18, which doubled is 36, and this divided by 9, the sum of the numbers, quotes 4 inches for the focal distance of the glass.

Since all those rays of the sun which pass through a convex glass are collected together in its *focus*, the force of all their heat is also collected in that part; and is in proportion to the common heat of the sun, as the *area* of the glass D E o the area of the focus: that is, the heat in the focus is as many times stronger than the common heat of the sun, as the area or surface of the glass exceeds the area or surface of the focus. For example: if the surface of a convex glass be twenty times that of its focus, the heat in the focus will be twenty times that of the common heat of the sun at the time. This is the reason that a convex glass causes the sun's rays to burn, or set fire to substances, upon which the focus is directed for some time.

All the rays which pass through the glass cross the middle ray in the focus *f*, (see last fig.) and then diverge from it to the contrary sides, in the same manner F *f* G, as they converged in the space D *f* E in coming to it.

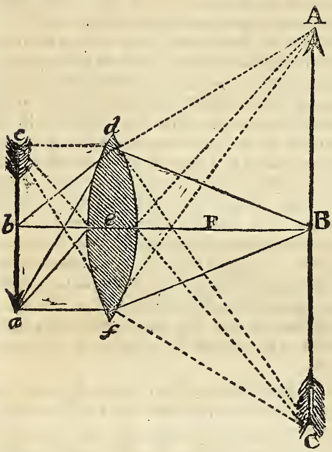
If another glass F G, of the same convexity as D E, be placed in the rays at the same distance from the focus, it will refract them so, as that after going out of it, they will be all parallel, as *a b c*; and go on in the same manner as they came to the first glass D E, through the space A B C; but on the contrary sides of the middle ray B *f b*: for the ray A D *f* will go on from *f* in the direction *f* G *a*, and the ray C E *f* in the direction *f* F *c*; and so of the others.

The rays diverge from any radiant point as if they came from a principal focus: therefore, if a candle be placed at *f*, in the focus of the convex glass F G, the diverging rays in the space F *f* G will be so refracted by the glass, as that after going out of it, they will become parallel, as shown in the space *c b a*.

If the candle be placed *nearer* the glass than its focal distance, the rays will diverge after passing through the glass, more or less, as the candle is more or less distant from the focus.

If the candle be placed *farther* from the glass than its focal distance, the rays will converge after passing through the glass, and meet in a point which will be more or less distant from the glass, as the candle is nearer to, or farther from, its focus; and where the rays meet, they will form an inverted image of the flame of the candle, which may be seen on a paper placed where the rays meet.

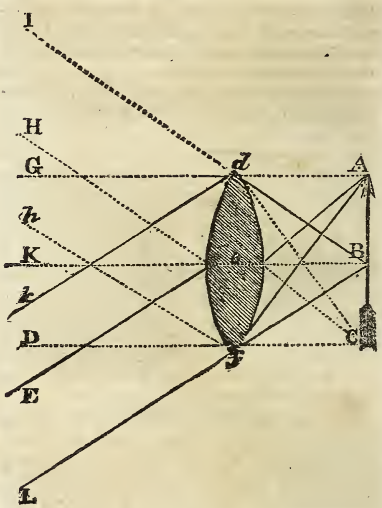
Hence, if any object A B C be placed beyond the focus F of the convex glass *d e f*,



some of the rays which flow from every point of the object, on the side next the glass, will fall upon it, and after passing through it, they will be converged into as many points on the opposite side of the glass, where the image of every point will be formed; and, consequently, the image of the whole object will be formed, and appear inverted.

Thus the rays A *d*, A *e*, A *f*, flowing from the point A, will converge in the space *d a f*, and by meeting at *a*, will there form the image of the point A. The rays B *d*, B *e*, B *f*, flowing from the point B, will be united at *b*, by the refraction of the glass, and will there form the image of the point B. And the rays C *d*, C *e*, C *f*, flowing from the point C, will be united at *c*, where they will form the image of the point C. And so of all the other intermediate points between A and C. The rays which flow from every particular point of the object, and are united again by the glass, are called *pencils* of rays.

If the object A B C be brought nearer to the glass, the picture *a b c* will be removed to a greater distance. For then, more rays flowing from every single point, will fall in a more diverging manner upon the glass; and therefore can not be so soon collected into the corresponding points behind it. Consequently, if the distance of the object A B C from the glass, be equal to the focal distance of the glass, the rays of each pencil will be so refracted by passing through the glass, that they will go out of it parallel to each other; as represented in the following figure.



Here the rays *d* I, *e* H, *f* h, which proceed from the point *c*, go out of the glass parallel to each other; the rays *d* G, *e* K, *f* D, which proceed from B, also proceed parallel to each other; and the rays *d* K, *e* E, *f* L, which proceed from A, observe the same law: this being the case, there can be no picture or image formed behind the glass.

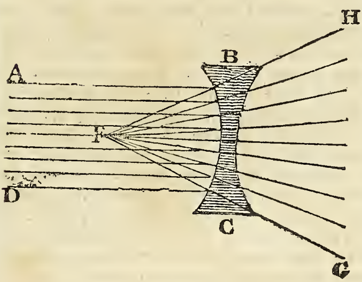
If the focal distance of the glass, and the distance of the object from the glass, be known, the distance of the image from the glass may be found as follows:—Multiply the distance of the focus by the distance of the object, and divide the product by their difference, the quotient will be the distance of the image from the glass. Thus:—suppose the focal distance of the glass to be 6 inches, and the distance of an object from it to be 8 inches, required the distance of the image from the glass. Here 8 multiplied by 6, is 48; which divided by 2, the difference between 8 and 6, quotes 24 inches for the distance of the image from the glass.

When any image is formed behind a glass, it will be as much bigger or less than the object as its distance from the glass is greater or less than the distance of the object. For as B *e* is to b *e*, so is A C to *a c*.* So that, if A B C be the object, *c b a* will be its image; or if *c b a* be the object, A B C will be the image.

* See the figure preceding the last.

Having now given a short account of the properties of convex lenses, we shall proceed to state the principal properties of concave ones, which will be very easily understood by those who have attentively read the foregoing observations upon convex glasses or lenses.

When parallel rays, as A D, pass directly through a glass or lens, as B C,



which is equally concave on both sides, they will diverge after passing through the glass, as if they had come from a radiant point F, in the centre of the glass's concavity; which point is called the *negative* or *virtual* focus of the glass. Thus the ray A, after passing through the glass B C, will go on in the direction B H, as if it had proceeded from the point F, and no glass been in the way. The ray D, after passing through the glass, will go on in the direction C G, and so on with the other intermediate rays. The ray F, that falls directly upon the middle of the glass, suffers no refraction in passing through it; but goes on in the same rectilineal direction as if no glass had been in its way. If the glass had been concave only on one side, and the other side quite plane, the rays would have diverged, after passing through it, as if they had come from a radiant point at double the distance of F from the glass; that is, as if the radiant point had been at the distance of a whole diameter of the glass's concavity.

If rays come to such a glass converging more than parallel rays diverge after passing through it, they will continue to converge after passing through it; but will not meet so soon as if no glass had been in the way; and will incline towards the same side to which they would have diverged, if they had come parallel to the glass.

As we have now stated the chief property of lenses, we shall give a short description of the structure of the Eye, and in doing this we shall be very brief, as we intend only to give the reader some idea how *vision* is performed by this most curious and noble organ.*

The eye is nearly globular, and consists of three *coats*, and three *humours*. The back part of the outer coat is called the *sclerotica*, and the front part of it *cornea*. The next coat within this is called the choroïdes, which serves, as it were, for a lining to the other, and joins with the *iris*. The *iris* is composed of two sets of muscular fibres; the one of a circular form, which contracts the hole in the middle, called the *pupil*, when the light would otherwise be too strong for the eye; the other consists of radial fibres, tending every where from the circumference of the iris towards the middle of the pupil; these fibres, by their contraction, have the effect of dilating and enlarging the pupil, when the light is weak, in order to let in the more rays. The third coat is only a fine expansion of the *optic nerve*, which spreads like net-work all over the inside of the choroides, and is therefore called the *retina;* upon which are formed the images of all visible objects, by the rays of light which either flow or are reflected from them.

Under the *cornea* is a fine transparent fluid, like water, which is therefore called the *aqueous humour*. This fluid gives a protuberant figure to the cornea, and has the same limpidity, specific gravity, and refractive power, as water.

At the back of this lies what is called the *crystalline humour*, which is shaped like a double convex glass; but a little more convex on the back than the fore part. It converges the rays which pass through it from every visible object to its focus, at the bottom of the eye. This humour is transparent like crystal, is much of the consistence of hard jelly, and exceeds the specific gravity of water in the proportion of 11 to 10. It is enclosed in a fine transparent membrane, from which proceed a number of radial fibres, all round the edge, and join to the circumference of the iris. These fibres have a power of contracting and dilating occasionally, by which means they alter the shape or convexity of the crystalline humour, and also shift it a little backward or forward in the eye, so as to adopt its focal distance at the bottom of the eye to the different distances of objects; without this provision we could only see those objects distinctly, that were all at one distance from the eye. At the back of the crystalline, lies the *vitreous* humour, which is transparent like glass, and is the largest of all in quantity,

* As a figure of the eye, and the necessary lines for explaining how vision is performed by it, is very complex, it was thought better to give only a verbal description of that organ.

filling the whole orb of the eye, and giving it a globular shape. In consistence it very much resembles the white of an egg; and very little exceeds the specific gravity and refractive power of water.

The crystalline humour is of such a convexity, that in a sound state of the eye, its focus falls precisely on the *retina*, and there paints or forms images of objects; and therefore vision is not distinct if the focus should either fall short or exceed the retina. If the convexity of the cornea and crystalline humour should be greater than the just degree for forming the images of objects distinctly on the retina, the focus of rays will fall short of the retina, and the images of objects will be formed before they fall upon the retina, which is the case with near-sighted or *purblind* persons.

If the convexity of those parts should be less than just, the focus will fall as it were beyond the retina, and the images of objects will not be formed under the retina as they should be, but above it in the crystalline humour, and, therefore will appear indistinct or confused.

CHEMISTRY.

The true etymology and origin of the word Chemistry is absolutely unknown. Both are enveloped in mystery, and lost in the darkness of ages past. Some historians of this science suppose its name to be derived from the word Kema, the pretended Book of Secrets, entrusted to women by the Demons; others derive it from Cham, the son of Noah, from whom Egypt received the name of Chemia, or Chamia; some attribute it to Chemnis, king of the Egyptians; and others deduce it from a Greek word, which signifies *juice*, because they suppose it to have commenced with the art of preparing juices, or from another Greek word, to *melt;* because, according to them, it is the daughter of the art of smelting the metals.

Authors have been almost as much at variance with respect to the definition as to the origin and etymology of chemistry. Some have confined it only to the art of examining, extracting and purifying bodies, particularly metals; others have only considered it as that of preparing remedies. It is only since the middle of the eighteenth century that chemistry has been considered the science which ascertains the principles of which bodies are composed, and their different properties. But even this last definition is not accurate, because it neither comprises all the productions of nature, the principles of some of which are unknown, nor all the means of the science, which are not confined merely to the separation of the constituent parts of bodies.

The true definition which ought to be given, in the present state of the science, is much more general. The following may be adopted:—Chemistry is a science by which we become acquainted with the intimate and reciprocal action of all the bodies in nature, upon each other. By the words *intimate* and reciprocal *action*, the science is distinguished from experimental philosophy, which only considers the exterior properties of bodies, possessing a bulk or mass capable of being measured; whereas chemistry relates only to the interior properties, and its action is confined to particles whose bulk and mass cannot be subjected to admeasurement or calculation. The action of the same cause may, by a change of circumstances, pass from being an object of the one of these sciences to become that of the other. The action of heat, when it expands or contracts the dimensions of bodies, belongs to natural philosophy; when the same power burns and consumes bodies, its action belongs to chemistry. When it converts water into steam it may belong to either science.

The object of Chemistry is to ascertain the ingredients of which bodies are composed; to examine the compounds formed by the combination of these ingredients; and to investigate the nature of the power which occasions these combinations.

The science, therefore, naturally divides itself into three parts:—1st. A description of the component parts of bodies, or of *simple substances*, as they are called. 2d. A description of the compound bodies formed by the union of simple substances. 3d. An account of the nature of the power which occasions these combinations. This power is now known in Chemistry by the name of *affinity*.

All the bodies in nature, considered with regard to the manner in which they are affected in chemical operations, present themselves to us either as simples or compounds:—that is, such as have not yet been decomposed, and such as have been analysed, or separated into others less composed, or complex. Whenever, therefore, we use the phrase *simple bodies* in Chemistry, the term is to be understood only of bodies not yet decomposed. We cannot assert that those bodies are really simple in themselves, or that they are not formed of other elements still more simple. We can only affirm, that in all the experiments which have been made, these bodies are found to act as if they were simple; that they cannot be decomposed by any process yet known; and that they can only be combined with other bodies, or made to form a component part of a compound body.

Natural bodies, considered under this point of view, present to chemists a very different aspect from what they did to those who held a different doctrine. Most of those bodies, which were formerly considered as simple and as the elements of all other bodies, are found to be more or less compounded; while many of those that were formerly considered as compounds are incapable of being decomposed, and can only be ranked among simple bodies.

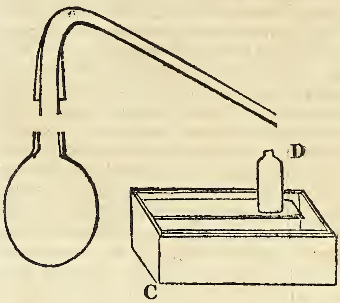
The simple substances at present known amount to about *fifty*. These are divided by Dr. Thomson into two classes, which he names *confineable* and *unconfineable* bodies. By the first he means solids and liquids; and by the last airs and gases, heat, light, &c. The former may be exhibited in a separate state, but the latter cannot; and their existence is inferred merely from certain appearances which the first class of bodies, and their compounds, exhibit in particular cases, and under peculiar circumstances. It is therefore obvious, that an acquaintance with the properties of the first set of bodies, is necessary in order to be able to investigate those of the second. We shall, therefore, consider these two classes separately.

But to form a classification of chemical facts, at once adapted to lead the student by *easy* and *certain* steps to a knowledge of this science, and at the same time conformable to the strict rules of philosophical arrangement, is attended with very great difficulty. For the science of Chemistry being chiefly confined to the investigation of the laws which bodies observe in combining together, or in separating from each other, it is impossible to enumerate the properties of any one substance which ought to be selected as the first object of investigation, without tracing the effects of many other bodies upon it, which must of necessity be previously known. The action of certain bodies is, however, much more general and extensive than that of others. It therefore appears to be the most natural order of considering this complex and extensive science, to begin by describing the properties and effects of one of the most important and singular substances in nature, which is *oxygen*.

OF OXYGEN GAS.

Oxygen gas may be obtained by the following process:—

Procure an iron bottle of the shape A,



and capable of holding rather more than an English pint. To the mouth of this bottle an iron tube bent like B is to be fitted by grinding. A gun-barrel deprived of its butt-end answers the purpose very well. Into the bottle put any quantity of the black oxide of manganese* in powder; fix the iron tube into its mouth, and the joining must be air-tight; then put the bottle into a common fire, and surround it on all sides with burning coals. The extremity of the tube must be plunged under the surface of the water with which the vessel C is filled.

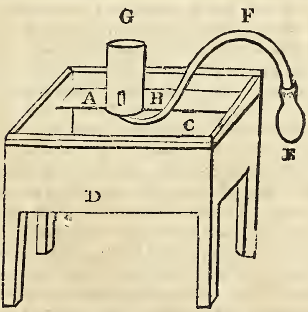
This vessel may be of wood or japanned tin-plate. It has a wooden shelf running along two of its sides, about three inches below the top, and an inch under the surface of the water. In one part of this shelf there is a slit, into which the extremity of the iron tube plunges. The heat of the fire expels the greatest part of the air contained in the bottle. It may be perceived bubbling up through the water of the vessel C from the extremity of the iron tube. At first the air-bubbles come over in torrents; but after having continued for some time they cease altogether.

Meanwhile the bottle is becoming gradually hotter. When it is obscurely red the air-bubbles make their appearance again, and become more abundant as the heat increases. This is the signal for placing the glass jar D, open at the lower extremity, previously filled with water, so as to be exactly over the open end of the gun-barrel. The air-bubbles ascend to the top of the glass jar D, and gradually displace all the water. The glass jar D then appears to be empty, but is in fact filled with air. It may be removed in the following manner:—Slide it away a little from the

* This substance shall be afterwards described. It is now very well known in Britain, as it is in common use with bleachers, and several other manufacturers, from whom it may be easily procured.

gun-barrel, and then dipping any flat dish into the water below it, raise it on the dish, and bear it away. The dish must be allowed to retain a quantity of water in it, to prevent the air from escaping. Another jar may then be filled with air in the same manner; and this process may be continued either till the manganese ceases to give out air, or till as many jarfuls have been obtained as are required.* This method of obtaining and confining air was first invented by Dr. Mayou, and afterwards much improved by Dr. Hales. All the airs obtained by this or any other process; or, to speak more properly, all the airs differing in their properties from the air of the atmosphere, have, in order to distinguish them from it, been called gases; and this name we shall afterwards employ.†

Oxygen gas may also be obtained in a different manner, thus:—Let D represent a wooden trough, the inside of which is lined with lead or tinned copper; and let C be a cavity in the trough, which ought to be a foot deep. The trough is to be filled with water at least an inch above the shelf AB, which runs along the inside of it, about three inches from the top. In the body of the trough, which may be called the cistern, the jars destined to hold gas are to be filled with water, and then to be lifted, and placed inverted upon the shelf at B.



This trough, which was invented by Dr. Priestley, has been called by the French chemists the *pneumato-chemical*, or simply *pneumatic* apparatus, and is extremely useful in all experiments in which gases are concerned. Into the glass vessel E put a quantity of black oxide of manganese in powder, and pour over it as much of that liquid which in commerce is called *oil of vitriol*, and in chemistry *sulphuric acid*, as is sufficient to form the whole into a thin paste; then insert into the mouth of the vessel the glass tube F, so closely that no air can escape except through the tube. This may be done either by grinding, or by covering the joining with a little glazier's putty, and then laying over it slips of bladder or linen dipped in glue, or in a mixture of the white of eggs and quicklime. The whole must be made fast with cord.*

The end of the tube F is then to be plunged into the pneumatic apparatus D, and the jar G, previously filled with water, to be placed over it on the shelf. The whole apparatus being fixed in that situation, the glass vessel E is to be heated by means of a lamp or candle. A quantity of oxygen gas rushes along the tube F, and fills the jar G. As soon as the jar is filled, it may be slid to another part of the shelf, and other jars substituted in its place, till as much gas has been obtained as is wanted. The last of these methods of obtaining oxygen gas was discovered by Scheele, the first by Dr. Priestley.

The gas obtained by the above processes was discovered by Dr. Priestley, on the 1st of August 1774, and called by him *dephlogisticated air*. Mr. Scheele, of Sweden, discovered it before 1777, without any previous knowledge of what Dr. Priestley had done: he gave it the name of *empyreal air*.* Condorcet gave it first the name of *vital air;* and Mr. Lavoisier afterwards called it *oxygen gas*; a name which is now generally received, and which we shall adopt.

1. Oxygen gas is colourless, and invisible like common air. Like it, too, it is elastic, and capable of indefinite expansion and compression.

2. If a lighted taper be let down into a phial filled with oxygen gas, it burns with such splendour that the eye can scarcely

* For a more exact description of this and similar apparatus, the reader is referred to Lavoisier's *Elements of Chemistry*, and Priestley *on Airs;* and above all to Mr. Watt's description of a *pneumatic apparatus*, in Beddoe's *Considerations on Factitious Airs.*

† The word gas was first introduced into Chemistry by Van Helmont. He seems to have intended to denote by it every thing which is driven off from bodies in a state of vapours by heat.

* This process, by which the joinings of vessels are made air-tight, is called *luting*, and the substances used for that purpose are called *lutes*. The lute most commonly used by chemists, when the vessels are exposed to heat, is fat lute, made by beating together, in a mortar, fine clay and boiled linseed oil. Bees-wax, melted with about one-eighth part of turpentine, answers very well, when the vessels are not exposed to heat. The accuracy of chemical experiments depends almost entirely in many cases upon securing the joinings properly with luting. The operation is always tedious; and some practice is necessary before one can succeed in luting accurately. Some very good directions are given by Lavoisier. See his *Elements*, Part. iii. chap. 7. In many cases luting may be avoided altogether, by using glass vessels properly fitted to each other by grinding them with emery.

bear the glare of light, and at the same time produces a much greater heat than when burning in common air. It is well known, that a candle put into a well-closed jar, filled with common air, is extinguished in a few seconds. This is also the case with a candle in oxygen gas; but it burns much longer in an equal quantity of that gas than of common air.

It has been ascertained by experiment, which shall be afterwards related, that atmospherical air contains 22 parts in the hundred (in bulk) of oxygen gas; and that no substance will burn in common air previously deprived of all the oxygen gas which it contains. But combustibles burn with great splendour in oxygen gas, or in other gases to which oxygen gas has been added. Oxygen gas, then, is absolutely necessary for combustion.

It has been proved also, by many experiments, that no breathing animal can live for a moment in any air or gas which does not contain oxygen gas mixed with it. Oxygen gas, then, is absolutely necessary for respiration.

When substances are burnt in oxygen gas, or in any other gas containing oxygen, if the air be examined after the combustion, we shall find that a great part of the oxygen has disappeared. If charcoal, for instance, be burnt in oxygen gas, there will be found, instead of part of the oxygen, another very different gas, known by the name of carbonic acid gas. Exactly the same thing takes place when air is respired by animals; part of the oxygen gas disappears, and its place is occupied by substances possessed of very different properties. Oxygen gas then undergoes some change during combustion, as well as the bodies which have been burnt; and the same observation applies also to respiration.

Oxygen gas is somewhat heavier than common air. If the specific gravity of common air be reckoned 1·000, that of oxygen gas, as determined by Mr. Kirwan, is 1·103. With this result the statement of Lavoisier agrees exactly. But Mr. Davy found it a little heavier; and Fourcroy, Vauquelin, and Seguin, found it a little lighter. Its specific gravity, according to Mr. Davy's experiments, is 1·127:* according to the French chemists, 1·087.

At the temperature of 60°, and when the barometer stands at 30 inches, 100 cubic inches of common air weigh very nearly 31 grains; and 100 cubic inches of oxygen gas, at the same temperature and pressure, weigh, according to Mr. Kirwan and Lavoisier, 34 grains; according to Sir H. Davy, 34·74 grains.

* Mr. Davy's oxygen gas was procured from oxide of manganese. It is possible that it contained a little *carbonic acid gas*. The tests used would not have excluded that body. This would explain its greater specific gravity.

Oxygen gas is not sensibly absorbed by water, except under great pressure; but by forcing it into a bottle of water by strong pressure, it may be made to absorb half its bulk of that gas, and to retain it in solution. Water thus impregnated does not sensibly differ from common water, either in taste or smell. It has been found a valuable remedy in several diseases.

Oxygen is capable of combining with a great number of bodies, and of forming compounds possessed of very different qualities.

As the combination of substances with each other is of the utmost importance in chemistry, we shall here make a few observations on that subject before we proceed to the consideration of the nature and properties of *Hydrogen Gas*.

When common salt is thrown into a vessel of pure water, it melts, and very soon spreads itself through the whole of the liquid, as any one may convince himself by the taste. In this case the salt combines with the water, and cannot afterwards be separated by filtration, or any other mechanical means. It may, however, be done by a very simple process; for, if a quantity of the spirit of wine be poured into the solution, the salt will fall slowly to the bottom of the vessel in the state of a very fine powder.

It was long ago asked, Why does the salt dissolve in water? and also, Why does it fall to the bottom on pouring in spirit of wine? These questions were first answered by Sir Isaac Newton.

There is a certain attraction between the particles of common salt and those of water, which causes them to unite together whenever they are presented to one another. There is also an attraction between the particles of water and spirit of wine, which equally disposes them to unite, and this attraction is greater than that between the water and salt; the water, therefore, leaves the salt to unite with the spirit of wine, and the salt being now unsupported, falls down by its weight to the bottom of the vessel. This power, which disposes the particles of different bodies to unite, was called by Newton *attraction*, by Bergman *elective attraction*, and by many of the German and French Chemists *affinity*; and this last term is now employed in preference to the others, because they are rather general. All substances which are capable of combining together, are said to have an *affinity* for each other; on the contrary, those substances which do not unite, are said to have no affinity for each other. Thus oil and water are said to have no affinity for one another.

It appears, from the instance of the common salt and spirit of wine, that substances differ considerably in the degree of their affinity from other substances, for the spirit of wine displaced the salt, and united with the water. Spirit of wine has, therefore, a stronger affinity for water than common salt has.

From facts of this kind tables of affinity have been formed and arranged in a very peculiar manner. The substance whose affinities are to be represented, is placed at the top of a column; and beneath it the bodies for which it has an attraction, placing those nearest to it which it attracts most strongly. Thus, in exhibiting the affinities of muriatic acid, the bodies for which it has an affinity would be placed thus:

MURIATIC ACID,

BARYTES,
POTASH,
SODA, &c.

This method is now universally adopted, and has contributed very much to the rapid progress of chemistry.

We shall treat this subject fully in a future number: we introduce it here merely to give the student of chemistry some idea of what is meant by bodies combining together, as the expression will frequently occur even in treating of simple bodies.

ASTRONOMY.

HISTORY OF ASTRONOMY.

[*Continued from page* 30.]

About this time, the Royal Society of London, and the Royal Academy of Paris, were established, each of which has produced astronomers of the first order. The first person appointed to conduct the observations at the royal observatory at Paris, was Dominic Cassini, who soon after discovered the first, second, third, and fifth satellites of Saturn. He also discovered that the planets Jupiter, Mars, and Venus turned round their axes in a manner similar to the earth. He died in the year 1712.

The successive propagation of light, one of the most curious discoveries in Astronomy, was about this time made by Roemer, a Danish astronomer. This has ever since been accounted a most essential element in Astronomy, and must secure immortality to the name of Roemer.

England, at all times, produced astronomers of the first order; and at this period it had to boast of Hook, Flamstead, and Halley.

Hook was born in 1635, and died in 1702. He was not only a great observer in every branch of Astronomy, but his inventive powers have been exhibited in almost every branch of science. He was the inventor of the Zenith Sector, an instrument which was used to determine whether or not the earth's orbit had any sensible parallax. He gave the first hint of making a quadrant for measuring angles by reflexion; and he, in some measure, anticipated the discoveries of Newton, by shewing that the motion of the planets resulted from a projectile force combined with the attractive power of the sun.

Flamstead was born 1646, and died in 1720. After the Royal Observatory at Greenwich was finished, he was appointed by King Charles II. to the management of it, with the title of Astronomer Royal. He made a very great number of observations, which he has recorded in his *Historia Celestis*, and in the Philosophical Transactions. But the principal service he rendered Astronomy, was by forming a catalogue of 3000 fixed stars visible in our climate.

Flamstead was succeeded, in 1719, by Dr. Halley, the greatest astronomer, says M. de la Lande, in England; and Dr. Long adds, "I believe he might have said the whole world." He was sent by King Charles II. to St. Helena, in order to form a catalogue of the stars in the southern hemisphere, which was published in 1679. While he was in the island of St. Helena, making this catalogue, he had an opportunity of observing a transit of Mercury across the sun's disc, by which he was enabled to point out the method of determining the parallax of the sun.

On his way between Calais and Paris, he obtained a sight of the famous comet that appeared in 1680, which suggested to him the idea of writing a treatise on the subject of comets, in which he investigates the orbits of these wandering bodies, and predicted the return of the one that appeared in 1759, which is the only prediction of the kind that ever was verified. It is said that during the nine years he was at Greenwich, he made 1500 observations. Halley was acquainted, either personally or by letter, with every astronomer of note in Europe then living. He died in the year 1742, aged eighty-six years; and was succeeded by Dr. Bradley, to whom we are indebted for two of the most beautiful discoveries of which the science can boast: the aberration of light, and the nutation of the earth's axis. He also made a great many observations, in order to discover if the fixed stars had any sensible parallax. These observations are partly published, and the remainder of them are in the hands of a Mr. Abraham Robertson, to whom their publication was entrusted. Bradley died in the year 1762.

But to no individual is the science of Astronomy more indebted, than to the celebrated Sir Isaac Newton. This great man was born on the 25th December 1642, at Woolstrope in Lincolnshire. His discoveries were not confined to Astronomy alone; for in Mathematics and Natural Philosophy he was equally great. His chief discovery in Astronomy was the law of gravitation, by which he was enabled to account for some of the greatest phenomena in nature. His great work, the Principia, appeared in 1686. This work is one of the most valuable books on Physical Astronomy that ever was published. His discoveries are so numerous and important in this science, that the solar system, or that restored by Copernicus, has received the appellation of the Newtonian system.

In this country there have been several distinguished astronomers since the time of Newton, among whom may be mentioned Dr. Long, Dr. Keil, Dr. Bliss, Mr. Ferguson, Mr. Hadley, and Dr. Herschel; the latter of whom, for his many accurate observations, deserves to be ranked among the first class of astronomers of any age or nation. In the year 1781, on the 13th of September, he discovered the planet Georgium Sidus. In the year 1787, he discovered two satellites revolving round that planet; and in 1790 and 1794, he discovered other two satellites. These discoveries of Herschel form a new era in Astronomy.

Dr. Maskelyne, the late Astronomer Royal, has likewise rendered very important service to the science. He was the first who proposed to the Board of Longitude the publishing of an Ephemeris or Nautical Almanack, which was begun in the year 1767. This almanack is still continued annually, and has been of the utmost service to navigation.

Dr. Maskelyne died a few years ago, and was succeeded by the present Astronomer Royal, Mr. Pond, who is also a man of genius, and promises to be of great service to Astronomy.

On the continent also there have been many astronomers of great talents since the time of Newton, particularly in France. Among these, La Caille deserves to be mentioned with credit. He was born in 1713, and in the year 1751 he undertook a voyage to the Cape of Good Hope, for the purpose of perfecting the catalogue of the stars in the southern hemisphere. After incredible labour and exertion, he returned to Europe with a catalogue of 9800 stars, which were comprehended between the south pole and the tropic of Capricorn. In addition to these labours, La Caille calculated new tables of the Sun, made observations on the parallax of Mars and Venus, on atmospherical refraction, on the length of pendulums, and measured a degree of the meridian during his stay at the Cape: he died in the year 1762. Contemporary with La Caille lived several very eminent astronomers, of whom may be mentioned Cassini, Bouguer, Condamine, Maupertuis, and Clairaut, who were all employed soon after this, in measuring degrees of the meridian in different parts of the world. Professor Mayer, of Gottingen, deserves also to be mentioned, as contributing greatly to the improvement of this science, by the excellent set of tables which he calculated for finding the place of the Moon, &c. These table are now used in making the calculations of the Nautical Almanack. His widow received £3,000 for them from the British Government, on account of their great accuracy. Mayer died in 1762, aged 41 years. D'Alembert also rendered great service to Astronomy by his indefatigable labours, particularly in resolving the problem of the precession of the equinoxes. He died 1783.

Euler, one of the greatest geniuses and calculators that any age or nation can boast of, ought to be associated with the history of Astronomy, as one of its most distinguished votaries and improvers. By his many and accurate calculations, he has rendered the most essential service, not only to Astronomy, but to all the physical sciences; but his labours are too numerous to be detailed here. The eighteenth century was distinguished by many other eminent astronomers; viz. Maclaurin, Simpson, Bernoulli, Lambert, Mason, Boscovich, De Lisle, Bailly, La Lande, &c.

The celebrated La Grange, who outlived most of his contemporaries, was born at Turin in 1736, and has enriched Astronomy with some of the most splendid discoveries of which it can boast. The subjects of his researches in this science were, the theory of Jupiter's satellites, the motions of the planets, and their action on each other, which he determined with great accuracy.

As the labours of the most distinguished astronomers that have appeared in the world have now been briefly noticed, and of whom their labours are the only memorials that exist; all that remains to complete this short account of the improvements that have taken place in the science, down to the present day, is to mention the labours of a few individuals still alive.

La Place has also distinguished himself by his labours to improve Astronomy, particularly in solving the problem of the tides,—in adding some new corrections to the lunar tables, and some discoveries respecting the precession of the equinoxes. He also ascertained the mean depth of the sea to be four leagues.

The name of Troughton ought also to be mentioned; for to no individual of the present age is *Practical Astronomy* more indebted than to this distinguished artist. The great improvements he has made upon astronomical instruments, has rendered his name celebrated in every country in Europe. There is scarcely an observatory of note to be found that does not contain some of Mr. Troughton's instruments.

The labours of Dr. Olbers, Harding, and Piazzi, will be noticed in treating of the new planets.

THE VARIOUS SYSTEMS OF ASTRONOMY.

By the word System, in Astronomy, is meant a collection or assemblage of celestial bodies, connected with each other by certain or fixed laws.

The system of the world comprehends the sun, the planets, and comets.

To explain the motions and appearances of these bodies, various hypotheses have, at different times, been formed; some of which have descended from the earliest periods to the present day, bearing the names of their respective inventors, and carry with them marks of very great powers of invention.

But in the earliest ages of the world, when men were ignorant of the laws of motion, it is scarcely to be expected that they could discover the true system of the universe, or explain all the various phenomena of the heavens. It is, however, believed, that the first opinions on this subject were much more just than those which were held afterwards for many years.

Pythagoras maintained, that the Earth was a planet, and that the sun was fixed in the centre of the planetary system. This is now universally believed; but at that time was only the opinion of a few individuals of Greece, who durst not openly avow such unpopular doctrine. Hence, in a very short time, the very name of the Pythagorean system was almost buried in oblivion.

PTOLEMAIC SYSTEM.

The first regular system of Astronomy that appeared in the world was the Ptolemaic, so called from Ptolemy, a native of Pelusium in Egypt, as already mentioned, who came to study in the school of Alexandria.

This system is represented by the following figure, where the concentric circles denote the orbits of the planets, &c.*

* The character ⊕ represents the Earth; ☽ the Moon; ☿ Mercury; ♀ Venus; ☉ the Sun; ♂ Mars; ♃ Jupiter; ♄ Saturn. The circle marked ✱ ✱ ✱ denotes the Firmament of Stars; I C the first crystalline sphere; II C the second crystalline sphere; and P M the *Primum Mobile.*

This system does not seem to have been originally invented by him, but adopted as the prevailing one of the age, which he digested into a system, more regular and consistent than any thing hitherto known on that subject. He supposed the Earth to be fixed immoveably in the centre of the universe, and that the sun, moon, and planets, moved round it. That above the planets were placed the firmament of stars, then two crystalline spheres, all of which were included in the *primum mobile*, which was, by some unaccountable means, turned round once in twenty-four hours, carrying all the rest along with it.

It is easy to see, that the confused motions of the planets here stated, could never be accounted for on any thing like *rational* principles. Had the planets circulated uniformly round the Earth, their apparent motions ought always to have been equal and uniform, without appearing either stationary or retrograde.

In consequence of this objection, Ptolemy was obliged to invent a great many circles interfering with each other, which he called Epicycles and Eccentrics. These proved an excuse for all the defects of his system; for, when any of the planets were deviating from the course they ought to have kept, they were then only moving in an epicycle or eccentric! But as to the natural cause which directed any of these bodies to move in these epicycles, he was at a loss to account, and was obliged to have recource to Divine power for an explanation; or in other words, to own that his system was unintelligible.

If this system were true, the two planets nearest the sun, Mercury and Venus, could never be hid behind the sun, as their orbits are included in his, (according to Ptolemy's hypothesis,) and these two planets would always move direct, and be as often in opposition as in conjunction with him. But the contrary of all this takes place; for these two planets are just as often behind the sun as before him; appear as often to move backward as forward; and are so far from being seen at any time in the side of the heavens opposite to the sun, that they were never yet seen a quarter of a circle in the heavens distant from him; which proves that this system is contrary to what actually takes place.

Yet it continued to be in vogue till the beginning of the sixteenth century, when Copernicus, a native of Thorn in Prussia, made his appearance. This man began, in the early part of his life, to try whether a more satisfactory manner of accounting for the apparent motions of the heavenly bodies could not be discovered, than what was given by Ptolemy. From intense application to the subject, and a few hints obtained from the ancients, he at last deduced a most complete system, capable of solving every phenomenon in a more satisfactory manner than was ever done before. This system is still called the

COPERNICAN SYSTEM.

In this system the Sun is supposed to be placed in the centre; next him revolves the planet Mercury, then Venus, next the Earth with the Moon; beyond these, Mars, Jupiter, and Saturn; and far beyond the orbit of Saturn is placed the fixed stars, which form the boundary of the visible creation. (See solar system.)

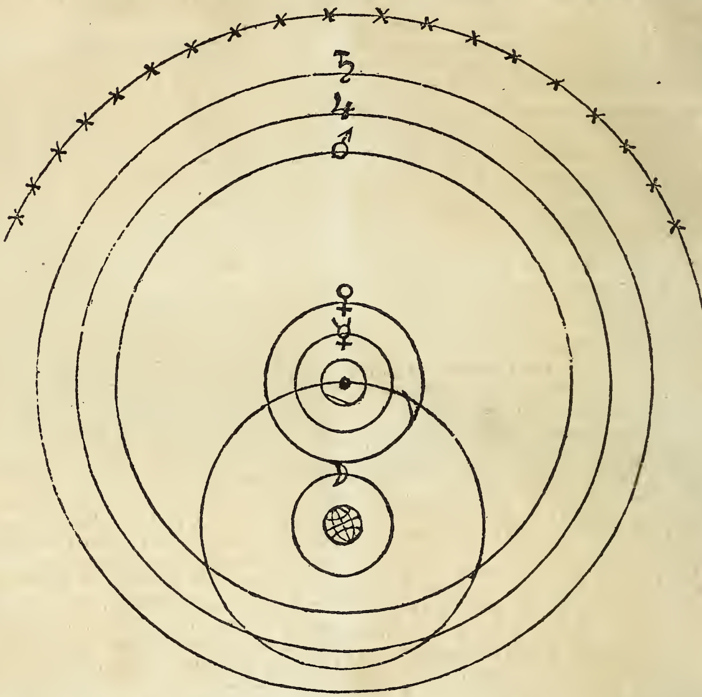
Copernicus concluded, that if the Earth revolved every day round its axis from *west* to *east*, all the heavenly bodies would appear to revolve in a contrary direction; namely, from *east* to *west*. The diurnal revolution of the heavens, upon this hypothesis, would be only apparent; the firmament, which has no other sensible motion, would be perfectly at rest; while the sun, the moon, and the five planets, would have no other motion beside that eastward revolution which is peculiar to them. By supposing the Earth to revolve with the planets round the sun in an orbit which included the orbits of Venus and Mercury, but included in those of Mars, Jupiter, and Saturn—he could, without the embarrassment of epicycles, connect together the apparent annual revolutions of the sun, and the direct, retrograde, and stationary appearances of the planets; and by supposing the axis of the Earth a little inclined to the plane of its orbit, and to remain always parallel to itself, he could also account for the obliquity of the ecliptic, the Sun's apparent progression from north to south, the consequent change of seasons, and the different lengths of days and nights, &c.

Though this system was received by most men of science then living, yet there were some who would never assent to it. The motion of the Earth was so contrary to what they were always accustomed to hear on that subject, and, as they thought, to appearances, that they could never agree to support such doctrine.

Among those who opposed the system of Copernicus, was the celebrated astronomer Tycho Brahe, who has already been mentioned as having greatly contributed to improve the science of Astronomy, by the number of observations which he made, and the excellent apparatus he caused to be constructed for his observatory. As he could not entirely adopt the Ptolemaic, and being a man of genius, he invented anothor system, which was a kind of mean between the Ptolemaic and the Copernican.

TYCHONIC SYSTEM.

According to Tycho Brahe, the inventor of this system, the Earth is supposed to be the centre of the orbits of the sun and moon; but the sun is supposed to be the centre of the orbits of the five primary planets then known. These orbits are represented by the following figure.



Thus, according to Tycho Brahe, the sun, and all the planets, moved round the Earth, in order to save the Earth from turning round her axis once in twenty-four hours.

This system, so repugnant to all the laws of Mechanics, was never very generally adopted, and is now mentioned only to be ridiculed. Tycho's true glory consisted in having been an excellent observer, and not in being the inventor of a new system.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR,—As I find it is not inconsistent with the plan of your interesting and very useful publication, to insert Philosophical Queries for solution, I have taken the liberty to enclose the following, which I will thank you to insert in a future number.—I am, Sir, &c. ANDREW ASKER.

. Suppose a balloon, containing 10000 cubical feet, to be filled with hydrogen gas, 13 times rarer than atmospheric air, under the same compression; and suppose the whole weight with which the balloon is loaded to be 350 pounds: required to what height it will ascend?

———

To the Editor of the Artisan.

SIR,—Having noticed several Philosophical queries in the 2d No. of the "Artisan," of which the answers are required; I would thank you to insert the two following questions in one of your future numbers, as I should wish to know their exact answers. I have solved them myself; but not having great confidence in my own powers of calculation, I should be obliged to you, or some of your mathematical readers, to give their answers, in order that I may compare them with my own, which I shall forward to you, should no one else deem them worthy of notice.

RERUM.

1. A gentleman erecting a house, whose breadth was twenty-eight feet, and back wall six feet nine inches higher than the front, had beside him a sufficient quantity of rafters for the front, each twenty-four feet long; which, to save timber, he was unwilling to cut, and therefore orders his builder to make the back rafters of such a length as will make the declivity of them and the front alike, for uniformity: required how he is to proceed?

2d. The outer diameter of a ring for the finger is ·9 of an inch, the inner diameter ·7, and thickness ·1 of an inch; the inside half of the ring, which touches the finger, is made of standard silver, and the outer half of standard gold: required the value of the ring, allowing five shillings for the expense of making it?

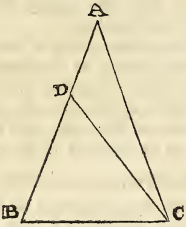
GEOMETRY.

PROPOSITION VI.

THEOREM.—*If two angles of a triangle be equal to one another, the sides which subtend,* or are opposite to, *the equal angles, shall also be equal to one another.*

Let A B C be a triangle, having the angle A B C equal to the angle A C B; the side A B is also equal to the side A C.

For, if A B be not equal to A C, one of them is greater than the other:—let A B be the greater, and from it cut off D B equal to A C, the less, and join D C;



therefore, because in the triangles D B C, A C B, D B is equal to A C, and B C common to both, the two sides D B, B C are equal to the two A C, C B, each to each; and the angle D B C is equal to the angle A C B; therefore, by the supposition, the triangle D B C is equal to the triangle A C B, the less to the greater; which is absurd. Therefore D B is not equal to A C, and in the same manner it may be proved, that no other straight line, greater or less than A B, can be equal to A C, wherefore A B is equal to A C, which was to be demonstrated.

Corollary.—Hence every equiangular triangle is also equilateral.

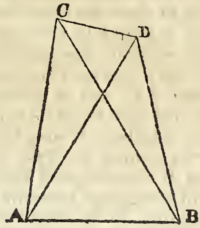
This proposition is the *converse* of proposition V, and its proof is by *reductio ad absurdum* (see page 17).

The corollary may be proved thus:—because the angle B is equal to the angle C, the side A C is equal to the side A B; and because the angle A is equal to the angle C, the side B C is equal to the side A B: therefore, the three sides A B, A C, and B C are equal to each other, which was to be shown.

PROPOSITION VII.

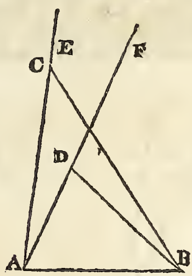
THEOREM.—*Upon the same base, and on the same side of it, there cannot be two triangles, that have their sides which are terminated in one extremity of the base equal to one another, and likewise those which are terminated in the other extremity, equal to one another.*

If it be possible, let there be two triangles A C B, A D B, upon the same base A B, and upon the same side of it, which have their sides C A, D A, terminated in A equal to one another, and likewise their sides C B, D B, terminated in B, equal to one another.



Join C D: then, in the case in which the vertex of each of the triangles is without the other triangle, because A C is equal to A D, the angle A C D is equal to the angle A D C: but the angle A C D is greater than the angle B C D; therefore the angle A D C is greater also than B C D; much more then is the angle B D C greater than the angle B C D. Again, because C B is equal to D B, the angle B D C is equal to the angle B C D; but it has been demonstrated to be greater than it; which is impossible.

But if one of the vertices, as D, be within the other triangle A C B;



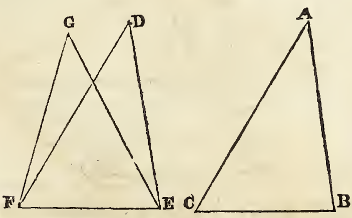
produce A C, A D to E, F; therefore, because A C is equal to A D in the triangle A C D, the angles E C D, F D C upon the other side of the base C D are equal to one another, but the angle E C D is greater than the angle B C D; wherefore the angle F D C is likewise greater than B C D; much more then is the angle B D C greater than the angle B C D. Again, because C B is equal to D B, the angle B D C is equal to the angle B C D; but B D C has been proved to be greater than the same B C D; which is impossible. The case in which the vertex of one triangle is upon a side of the other, needs no demonstration.

Many of the propositions in Euclid are merely *subsidiary;* that is, they are in themselves of no other use, than as necessary to the proof of other propositions that are useful:—of this kind are propositions VII, XVI, and XVII of the first book. The demonstration of this proposition is another instance of *reductio ad absurdum;* we here suppose an impossibility to be possible, in order to shew the absurdity of that supposition: a figure is here *made* to represent what no figure can represent: *i. e.* an impossibility;—for we suppose not only that the lines A C and A D are equal to one another, but also that C B and D B are equal to one another, which the demonstration shews cannot be true, unless the points C and D coincide, and then the two triangles will altogether coincide and form but one triangle. It is possible that A C and A D, terminated at the extremity A, may be equal; but then C B and D B, terminated at the extremity B, cannot be equal:—in like manner, C B and D B may be equal, but if they are, A C and A D cannot; and this is all that was required to be proved

PROPOSITION VIII.

Theorem.—*If two triangles have two sides of the one equal to two sides of the other, each to each, and have likewise their bases equal; the angle which is contained by the two sides of the one shall be equal to the angle contained by the two sides of the other.*

Let A B C, D E F be two triangles, having the two sides A B, A C, equal to the two sides D E, D F, each to each; viz. A B to D E, and A C to D F; and also the base B C



equal to the base E F. The angle B A C is equal to the angle E D F.

For, if the triangle A B C be applied to the triangle D E F, so that the point B be on E, and the straight line B C upon E F; the point C shall also coincide with the point F, because B C is equal to E F; therefore B C coinciding with E F, B A and A C shall coincide with E D and D F; for, if B A and C A do not coincide with E D and F D, but have a different situation, as E G and F G; then, upon the same base E F, and upon the same side of it, there can be two triangles E D F, E G F, that have their sides which are terminated in one extremity of the base equal to one another, and likewise their sides terminated in the other extremity:—but this is impossible; therefore, if the base B C coincides with the base E F, the sides B A, A C cannot but coincide with the sides E D, D F; wherefore likewise the angle B A C coincides with the angle E D F, and is equal to it. Therefore, if two triangles, &c. Q. E. D.

This proposition is a second instance of a proof, by supposing the one figure placed upon the other; and since it is shewn that the triangles so applied completely coincide, it follows from the 8th axiom, that the triangles are equal; that the sides of the one are respectively equal to the sides of the other; and the angles of the one to the angles of the other.

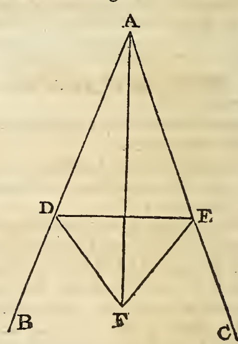
Hence, if the three sides of one triangle be respectively equal to the three sides of another, the two triangles will be both equal, and equiangular to each other: that is, the angles of the one will be respectively equal to the angles of the other.*

PROPOSITION IX.

Problem.—*To bisect a given rectilineal angle; that is, to divide it into two equal angles.*

Let B A C be the given rectilineal angle, it is required to bisect it.

Take any point D in A B, and from A C cut off A E equal to A D; join D E, and upon it describe an equilateral triangle D E F; then join A F; the straight line A F bisects the angle B A C.



Because A D is equal to A E, and A F is common to the two triangles D A F, E A F; the two sides D A, A F, are equal to the two sides E A, A F, each to each; but the base D F is also equal to the base E F; therefore the angle D A F is equal to the angle E A F; wherefore the given rectilineal angle B A C is bisected by the straight line A F. Which was to be done.

* The converse of this proposition, viz. that triangles equiangular to each other, are also equilateral to each other, is not true. (See p. 18, and note.)

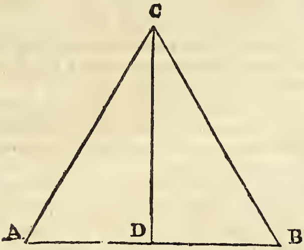
From this proposition it appears, that the bisection of an angle is very easily performed; the trisection is however more difficult, and cannot be performed by elementary Geometry.

PROPOSITION X.

Problem.—*To bisect a given straight line; that is, to divide it into two equal parts.*

Let A B be the given straight line; it is required to divide it into two equal parts.

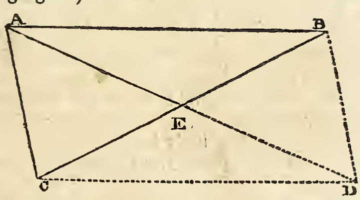
Describe upon it an equilateral triangle A B C, and bisect the angle A C B by the straight line C D. A B is cut into two equal parts in the point D.



Because A C is equal to C B, and C D common to the two triangles A C D, B C D: the two sides A C, C D are equal to the two B C, C D, each to each; but the angle A C D is also equal to the angle B C D; therefore the base A D is equal to the base D B, and the straight line A B is divided into two equal parts in the point D: which was to be done.

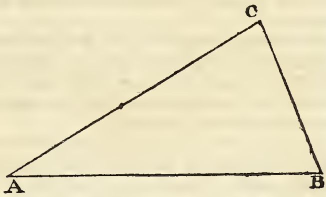
MECHANICS.

If any lines D B, B C, C A, and A E, (see the figure at page 24, col. 2d,) taken in order, represent the quantities and directions of forces communicated at the same time to a body at D, the line D E, which completes the figure, will represent a force equivalent to them all. For the two lines D B and B C are equivalent to D C; also, D C and C A, that is, D B, B C, and C A, are equivalent to D A; in the same manner D A, and A E, are equivalent to D E. Therefore, if A B and A C, in the following figure,



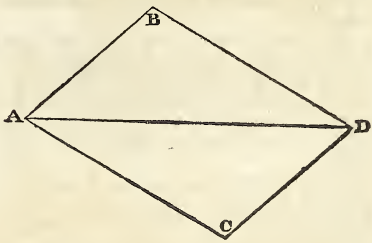
represent the quantities and directions of two forces, and if A E be drawn to bisect B C, then will *twice* A E represent a force equivalent to them both. For if the parallelogram be completed, since the diagonals A D and B C bisect each other, A D, which represents a force equivalent to A B and A C, is equal to *twice* A E.

If a body at rest be acted upon at the same time by three forces, which are represented in quantity and direction by the *three* sides of a triangle, taken in order, it will remain at rest. For let A B, B C, and C A, represent the quantities and directions of three forces, acting at the same time upon a body at A;



then, since A B and B C are equivalent to A C; A B, B C, and C A are equivalent to A C and C A; but A C and C A are equal and in opposite directions, therefore, must keep the body at rest, consequently the three forces A B, B C, and C A will keep the body at rest.

A single force may be resolved into any number of forces. For since the single force A D is equivalent to the two, A B and B D, it may be conceived to be made up of, or resolved into, the two, A B and B D.



The force A D may therefore be resolved into as many pairs of forces as there can be triangles described upon A D, or parallelograms about it. In like manner A B or B D may be resolved into two; and, by proceeding in the same way, the original force may be resolved into any number of forces.

OF FALLING BODIES.

It has already been stated, at page 8, col. 1st, that when a body falls from any considerable height, its motion is uniformly accelerated, or its velocity increases proportionally to the time; this effect is produced by what is termed *gravitation*, or the power of gravity, and it affects all falling bodies in an equal degree; that is, they all fall from equal heights in equal portions of time, whatever their weights may be, allowance being made for the resistance of the air on the greater body, as is proved by experiments made with the air-pump. It has also been found, by experiments made on heavy bodies, that when they fall freely, in vacuo, or in a vessel from which the air has been extracted, that they descend from rest through the space of $16\frac{1}{12}$ feet in the first second of time.

This fact being established, every thing relating to falling bodies is comprehended in the few simple propositions, which follow.

The *velocity* acquired by a body falling from rest in any given time, is equal to twice the space fallen through in one second of time, multiplied by the number of seconds it has been in motion.

Hence, as a body falls $16\frac{1}{12}$ feet in one second, it acquires a velocity, at the end of that time, which would carry it $32\frac{1}{6}$ feet in the next second, although it acquired no new impulse from gravity; but as it is continually accelerated, it will have acquired a velocity, at the end of *two* seconds, which would carry it $64\frac{1}{3}$ feet, and so on, increasing proportionally to the time.

The *whole space* fallen through in any given time is equal to $16\frac{1}{12}$ feet, multiplied by the square of the time, reckoned in seconds: hence it is easy to ascertain the space which any body has fallen through when the time it has been in falling is known.

The *time* which any body will fall through any given *space* is obtained by dividing the space by $16\frac{1}{12}$, and extracting the square root of the quotient, the last result is the number of seconds the body has been in descending through the given space.

The *time* that a falling body will have acquired any given *velocity* may also be determined thus: divide the velocity by $32\frac{1}{6}$, and the quotient will be the time in seconds.

These are the chief propositions relating to bodies falling to the earth, which we shall illustrate by one or two numerical examples, in order to render them still more intelligible to those who are not much acquainted with calculation.

1. What is the velocity acquired by a body which has fallen from a state of rest, after it has been three seconds in motion? —Here $32\frac{1}{6}$, multiplied by 3, gives $96\frac{1}{2}$ feet, the velocity required.

2. How many feet will a body, which descends from rest, fall in three seconds of time?—Here $16\frac{1}{12}$, multiplied by 9, the square of 3, gives $144\frac{3}{4}$ feet, for the whole space fallen through in three seconds.

3. In what time will a body descend from rest through the space of $257\frac{1}{3}$ feet? —Here $257\frac{1}{3}$, divided by $16\frac{1}{12}$, quotes 16, the square root of which is 4, the number of seconds required.

4. In what time will a body, which has fallen from rest, acquire a velocity of $128\frac{2}{3}$ feet?—Here $128\frac{2}{3}$, divided by $32\frac{1}{6}$, quotes 4, the number of seconds in which the body will acquire the given velocity.

From what has here been stated respecting bodies falling from rest, and descending by the force of gravity, it appears, that the spaces described by them in any equal successive portions of time, reckoning from the beginning of the motion, are as the numbers 1, 3, 5, 7, &c. Thus the spaces fallen through in the 1st, 2d, 3d, and 4th seconds of time, are $16\frac{1}{12}$, $16\frac{1}{12}$ multiplied by 3, $16\frac{1}{12}$ multiplied by 5, $16\frac{1}{12}$ multiplied by 7 feet respectively.

If a body projected upwards move till its whole velocity is destroyed, the spaces described in equal successive portions of time, are as the numbers 1, 3, 5, 7, &c., as in falling bodies, but taken in an inverted order. Thus, if the velocity be wholly destroyed in four seconds, the spaces described in the 1st, 2d, 3d, 4th seconds, are $16\frac{1}{12}$ multiplied by 7, $16\frac{1}{12}$ multiplied by 5, $16\frac{1}{12}$ multiplied by 3 feet respectively.

If a body be projected perpendicularly upwards, the height to which it will ascend in any given time, is equal to the space through which it would move with the first velocity continued uniform, diminished by the space through which it would fall by the action of gravity in that time.

1. For example: To what height will a body rise in three seconds, if projected perpendicularly upwards, with a velocity of 100 feet per second?—The space which the body would describe in three seconds, with the first velocity, is 300 feet; and the space through which the body would fall by the force of gravity in three seconds, is $16\frac{1}{12}$ multiplied by 9, or $144\frac{3}{4}$ feet; therefore the height required is 300 diminished by $144\frac{3}{4}$, or $155\frac{1}{4}$ feet.

2d. Again: If a body be projected perpendicularly upwards with a velocity of 80 feet per second, required its place at the end of six seconds?—The space which would be described in six seconds, with the first velocity, is 480 feet, and the space fallen through in the same time is $16\frac{1}{12}$ multiplied by 36, or 579 feet; therefore the distance of the body from the point of projection, at the end of six seconds, is 480 diminished by 579, or minus 99 feet, which signifies that the body has descended 99 feet below the point from which it was projected.*

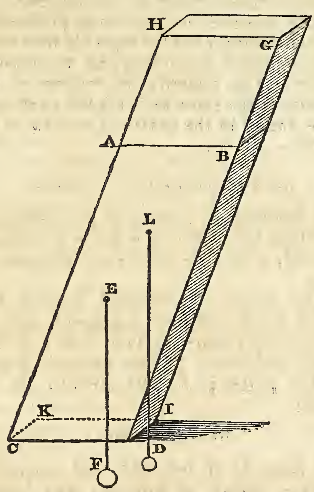
* In all the foregoing observations on falling bodies, the *time* is supposed to be reckoned in seconds.

OF THE CENTRE OF GRAVITY.

The *centre of gravity* is that point of a body in which the whole force of its gravity or weight is united. Therefore, whatever supports that point bears the weight of the whole body: and whilst it is supported, the body cannot fall; because all its parts are in perfect equilibrium about that point.

An imaginary line drawn from the centre of gravity of any body towards the centre of the earth, is called the *line of direction*. In this line all heavy bodies descend, if not obstructed.

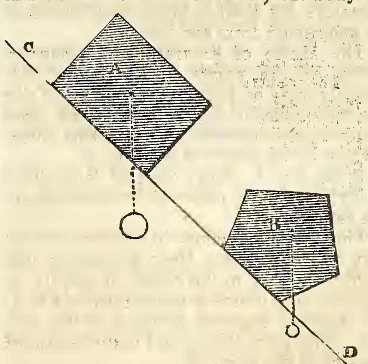
Since the whole weight of a body is united in its centre of gravity, as that centre ascends or descends, we must look upon the whole body to do so too. But as it is contrary to the nature of heavy bodies to ascend of their own accord, or not to descend when they are permitted, we may be sure that, unless the centre of gravity be supported, the whole body will tumble or fall. Hence it is, that bodies stand upon their bases when the line of direction falls within the base; for in this case the body cannot be made to fall without first raising the centre of gravity higher than it was before. Thus, the inclining body A B C D,



whose centre of gravity is E, stands firmly on its base C D I K, because the line of direction E F falls within the base. But if a weight, as A B G H, be laid upon the top of the body, the centre of gravity of the whole body and weight together is raised up to L; and then, as the line of direction L D falls without the base at D, the centre of gravity L is not supported; and the whole body and weight will tumble down together.

Hence appears the absurdity of people's rising hastily in a coach or boat when it is likely to overset: for, by that means they raise the centre of gravity so far as to endanger throwing it quite out of the base; which, if they do, they overset the vehicle effectually. Whereas, had they clapt down to the bottom, they would have brought the line of direction, and consequently the centre of gravity, farther within the base, and by that means might have saved themselves.

The broader the base is, and the nearer the line of direction is to the middle or centre of it, the more firmly does the body stand. On the contrary, the narrower the base, and the nearer the line of direction is to the side of it, the more easily is the body overthrown, less change of position being sufficient to remove the line of direction out of the base in the latter case than in the former. And hence it is, that a sphere is so easily rolled upon a horizontal plane; and that it is so difficult, if not impossible, to make things which are sharp pointed stand upright on the point. From what has just been stated, it plainly appears that if the plane be inclined, on which the heavy body is placed, the body will *slide* down upon the plane whilst the line of direction falls within the base; but it will *tumble or roll down* when that line falls without the base. Thus, the body A



will only slide down the inclined plane C D, whilst the body B rolls down upon it.

When the line of direction falls within the base of our feet, we stand; but when it is without that base, we immediately fall. And it is not only pleasing, but even surprising, to reflect upon the various and unthought-of methods and postures which we use to retain this position, or to recover it when it is lost. For this purpose we bend our body forward when we rise from a chair, or when we go up stairs: and for this purpose a man leans *forward* when he carries a burden on his back, and *backward* when he carries it on his breast; and to the right or left side as he carries it on the opposite side.

Every *system* of bodies, therefore, and every individual body, (for a single body may be regarded as a system of particles or infinitely small bodies), has a centre of gravity; and that centre remains the same while the bodies retain their position relatively to one another, however the whole system may change its place relatively to the horizon.

The distance of the centre of gravity of any system of bodies from a given plane, is equal to the sum of the products of all the masses into their distances from the plane, divided by the sum of the masses.*

Thus required the centre of gravity of three bodies placed in the same straight line, their weights being 6, 8, and 12 pound; and their distances from a point in the same 20, 30, and 40 inches respectively. Here the product of each body multiplied into its distance from the given point, added into one sum is 840, which, divided by 26, the *weight* of the bodies, quotes $32\frac{4}{13}$ inches, the distance of the centre of gravity from the given point.

If the bodies are on different sides of the point to which their distances are referred, those on one side are to be accounted *affirmative*, and those on the other *negative;* therefore the least of these quantities is to be subtracted from the greater.

The centre of gravity of a *triangular plane*, all the points of which gravitate equally, may be found as follows:—From the two angles of the triangle, draw lines bisecting the opposite sides. Their intersection is the centre of gravity.

When this is done, each of these lines is divided by the point of intersection, in the ratio of 2 to 1.

The centre of gravity of a given *pyramid* may be found thus: Draw a straight line from the vertex to the centre of gravity of the base, and divide it in the ratio of 3 to 1, the greatest segment being next the vertex. The point thus found is the centre of gravity of the pyramid.

This construction applies to a pyramid of *any* number of sides, and consequently to a *cone*.

The centre of gravity of any plane may be found mechanically.

Suspend it by a given point in or near its perimeter, and when it is at rest, draw across it a vertical line passing through that point, suspend it in like manner by another point, and draw a vertical line as before. The intersection of these lines is the centre of gravity of the plane.

If the body be of three dimensions, that is, solid, the same process may be followed; but *three* suspensions will be necessary.

In the preceding propositions, the centres of gravity of bodies or systems, in which the parts preserved the same relative position, have only been considered. It is evident, however, that in any system, though the parts be not fixed in the same relative position, the centre of gravity for any given position may be found; and there are some general properties of the centres so found, that are very important in mechanics.

If any number of bodies move uniformly in straight lines, their common centre of gravity will also move uniformly in a straight line, or will remain at rest.

The mutual action of bodies does not change the state of their centre of gravity, either as remaining at rest, or as moving uniformly in a straight line.

It is also known that the quantity of motion in any system of bodies estimated in a given direction, remains constantly the same, whatever may be the mutual action of these bodies on one another.

Both this and the preceding proposition are consequences of the equality that takes place between the action and re-action of bodies. The quantity of motion in any system, is the same as if all the parts of it were united in the centre of gravity of the whole.

ON THE MECHANICAL POWERS.

A mechanical power, is an instrument by which the effect of a given force is increased, while the force itself remains the same.

The simple mechanical powers into which more complex machines are resolved, are these: 1. The lever; 2. The wheel and axle; 3. The inclined plane; 4. The pulley; 5. The wedge; 6. the screw.

OF THE LEVER.

A lever is an inflexible rod, moveable about a centre or fulcrum, and having forces applied to two or more points in it.

The simplest state of the lever is, when there are only two forces; and of this there are two cases; in the first, the fulcrum is between the points where the forces are applied, and the forces are directed the same way; in the second, the points to which the forces are applied, are

* As a single body may be regarded as a system of particles, this proposition applies to such bodies, and is therefore universal.

on the same side of the fulcrum, and the forces are directed opposite ways.*

In treating of the lever, it is usual to distinguish the forces by the names of the Power and the Weight, or the Power and the Resistance,—terms that have a reference to the intention with which the machine is used, not to any real difference in the action of the forces.

In treating of the lever, we shall begin with abstracting entirely from its own weight.

If two forces be applied to a lever having equal and opposite *momenta*; that is, tending to produce motion in opposite directions, and being inversely as the perpendiculars drawn to their direction from the fulcrum, they will be in equilibrium with one another. Thus, suppose the length of a lever to be 8 feet long, with a weight of 180 pounds at one end, 2 feet from the fulcrum, or prop; and a weight of 45 pounds at the other, 6 feet from the fulcrum: these weights will be in equilibrium, because they are to each other *inversely* as their perpendicular distances from the fulcrum upon which they rest; that is, the greater weight contains the lesser, as many times as the distance of the lesser contains the distance of the greater from the fulcrum.

When the forces or weights act parallel to one another, as has been supposed in the example just given, this proposition coincides with the property of the centre of gravity, mentioned at page 53†. When they act in an *oblique* direction, the case may be reduced to the preceding by the resolution of forces.

It may be proper to remark, before proceeding to treat more particularly of the lever, that the properties, as well as the effects that may be produced by any of the mechanical powers, is best explained and illustrated, by showing when an equilibrium takes place between the power and the resistance, where any of these instruments are concerned. For when an equilibrium is produced, the least addition to the power must make it overcome the resistance.

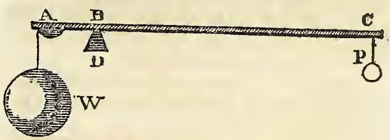
If any number of forces be applied to a lever, there will be an equilibrium, if the sums of the opposite momenta be equal to one another, and therefore, this proposition also coincides with a property of the centre of gravity. See page 53.

The *converse* of this proposition is also true, and as it is common to all the mechanical powers, and in fact to all machines whatever, we shall here state it in the form of a distinct proposition, as follows: When there is an equilibrium in the lever, the sum of the momenta on one side of the centre of motion, is equal to that on the other.

This property of machines is known by the name of the principle of *virtual velocities*, and is of great use in mechanical investigations.

The different cases of the lever, whether it be straight or crooked; and the forces *perpendicular* or *oblique*, are all comprehended in the preceding propositions. The case of *oblique* forces, however, admits of a very concise expression in terms of the angles; we shall therefore insert the proposition containing the principle upon which this property depends, though it can only be fully understood by those who have a slight knowledge of trigonometry. It is this,—if two oblique forces be applied to the extremities of a straight lever, there will be an equilibrum between them, if they be inversely as the lengths of the arms by which they act, multiplied into the *sines* of the angles, which their directions make with the lever. This proposition is general, and therefore comprehends the case of perpendicular forces; it is, however, unnecessary to illustrate this by an example, for the reason stated above; we shall, therefore, now explain the different *kinds* of levers, and state the particular properties of each variety.

A lever of the first kind is represented by the bar, or rod A B C, supported by the prop D:



its principal use is to loosen large stones in the ground, or raise great weights to small heights, in order to have ropes put under them for raising them higher by other machines. The parts A B and B C, on different sides of the prop D, are called the *arms* of the lever: the end A of the shorter arm A B is applied to the weight intended to be raised, or to the resistance to be overcome; and the power is applied to the end C of the longer arm B C.

In making experiments with this instrument, the shorter arm A B must be as much thicker than the longer arm B C, as will be sufficient to balance it on the prop. This being supposed to be the case, let P represent a power, whose weight is equal to one pound, and W a body, whose

* Some writers on mechanics divide levers into *three* kinds; but *two* of these are reducible to the second kind mentioned in this proposition.

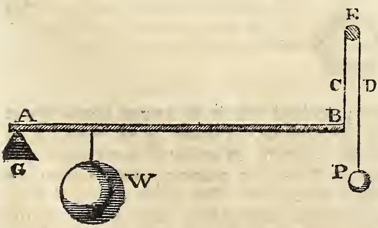
† Therefore the fulcrum and centre of gravity coincide; or the fulcrum supports the centre of gravity of the whole.

weight is equal to 12 pounds. Then, if the power be twelve times as far from the prop as the weight is, they will exactly counterpoise each other; and a small addition to the power P will cause it to descend, and raise the weight W; and the velocity with which the power descends will be to the velocity with which the weight rises, as 12 to 1: that is, directly as their distances from the prop; and, consequently, as the spaces through which they move. Hence it is plain, that if a man, by his natural strength, without the help of any machine, could support an hundred weight, he will, by the help of this lever, be enabled to support 12 hundred. If the weight be less, or the power greater, the prop may be placed so much farther from the weight; and then it can be raised to a proportionably greater height. For, as has already been stated, if the weight, multiplied into its distance from the prop, be equal to the power multiplied into its distance from the prop, the power and weight will exactly balance each other; and a little addition to the power will raise the weight.

To this kind of lever may be reduced several kinds of instruments, such as scissors, pincers, snuffers, which consist of two levers acting contrary to each other, their prop, or centre of motion, being the pin which holds them together.

In common practice the longer arm of this kind of lever considerably exceeds the length of the shorter arm, and, of course, gives great advantage, because it adds so much to the power.

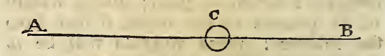
A lever of the second kind has the weight between the fulcrum and the power, as represented by A B in the following figure.



In this species of lever, as well as in the former, the advantage gained depends upon the distance of the power from the fulcrum, compared with that of the resistance, or weight from the same point; for the respective velocities of the power and weight are in proportion to their distances from the fulcrum, and they will be in equilibrium when the weight of the power, multiplied by its distance from the fulcrum, is equal to the weight or resistance, multiplied by its distance from the fulcrum.

Thus, suppose the weight W equal to 36 pounds, and to hang one foot from the prop G; and suppose a power P, equal to six pounds, to hang at B, six feet from the prop, by means of the cord C D going over a fixed pulley E, the power will, in this case, just support the weight; and a small addition to the power will cause it to raise the weight; but the power will descend through six times the space that the weight will ascend in any given time.

A lever of this kind shows why two men carrying a burden upon a stick between them, bear unequal shares of the burden, if it is not placed at equal distances from each of them. For when a weight is placed upon a lever which is supported upon two props, in a horizontal position, as A and B,



the pressure upon A is to the pressure upon B, as the distance B C is to the distance A C.

Hence, if a weight be placed on a stick, as at C, three times nearer B than A, and if one man support the end A and another the end B, the one at B supports three times as much weight as the one at A.

This is likewise applicable to the case of two horses of unequal strength, so yoked, as that each horse may draw a part proportionable to his strength; which is done by dividing the beam in such a manner, as that the point of *traction* may be as much nearer to the stronger horse as his strength exceeds that of the weaker.

To this kind of lever may be reduced oars, rudders of ships, doors turning upon hinges, cutting-knives that are fixed at the point of the blade, &c.

HYDROSTATICS.

ON THE EFFECTS OF CAPILLARY TUBES.

If a capillary tube of glass; that is, a tube of which the bore is less than one-tenth of an inch, be immersed in water, the water will rise within the tube to a greater height than it stands at on the outside; and this height is nearly in the inverse ratio of the diameter of the tube; that is, the less the diameter the higher will the water rise. For a tube of which the bore is $\frac{1}{100}$th of an inch, the rise is 5·3 inches. So the product of the diameter of the tube, into the height to which the water rises, is a given quantity, and nearly equal to ·053, in parts of a square inch.

It follows also from the above, that the weights of the columns of water sustained in capillary tubes, are in proportion to the diameters of these tubes.

Though the rise of water above its natural level is most manifest in small tubes, it appears, in a degree, in all vessels whatsoever, by a ring of water formed round the sides, with a concavity upwards.

Capillary suspension takes place, though the tube be not immersed in water, providing a drop of water adhere to the lower end of it.

The surface of the water in a capillary tube is concave upwards; and if by taking the tube out of the water, and inclining it, the fluid be made to move along it, the concavity appears at both ends of the column, and is the same in figure and size, whether the tube be held perpendicularly, horizontally, or obliquely.

When by inclining the tube, the column of water is made to move, it appears to suffer resistance as it approaches either end, and does not completely reach the end, till the tube is either altogether, or very nearly inverted.

When the tube is placed in the water, however far it be thrust down, the water within never reaches the top, till the tube is completely immersed.

If a capillary tube composed of two cylinders of different bores, be immersed in water, first with the widest part downwards, and afterwards with the narrowest, the water will rise in both cases to the same height.

If the smaller end is such as to require the whole to be filled by suction, the water stands at the same height as if the whole tube were of the bore of the upper part. This experiment, however, does not succeed *in vacuo*, and therefore the water in the wide part of the tube must be considered as sustained by the pressure of the air.

If two plates of glass be kept parallel, and near to one another, and if their ends be immersed in water, the water will ascend between them to half the height it would rise to in a tube, having its diameter equal to the distance of the plates.

When the plates make an angle with one another, if they be immersed with the line of their intersection vertical, the water will ascend between them, and form a hyperbola.

La Place caused experiments to be made with one tube placed within another, so that their axes coincided, and found that the water ascended in the space between them, only half as high as it would have done in a single tube, in which the diameter of the bore was equal to the distance of the two tubes from one another.

If a glass tube of a small bore be immersed in mercury, the mercury does not rise within the tube to the height at which it stands on the outside; its surface within is *convex*, as it is also without, all round the tube.

If into a conical capillary tube, held in a horizontal position, a drop of water be introduced, it will run toward the narrow end; but if a drop of mercury be introduced, it will run toward the wide end.

Whether a fluid rise or fall between two vertical and parallel planes, immersed in the fluid at their lower extremities, the planes tend to approach one another.

It is from this tendency, that two small vessels of glass, of a parallelopiped form, floating on water or mercury, unite, whenever they approach near to one another.

The phenomena here enumerated, clearly prove the existence of an attractive force between water and glass, but require to be carefully compared before we can judge of the manner in which that force is exerted. The fact that points most directly to the place where the force resides, is that of the concavity of the surface, as already mentioned.

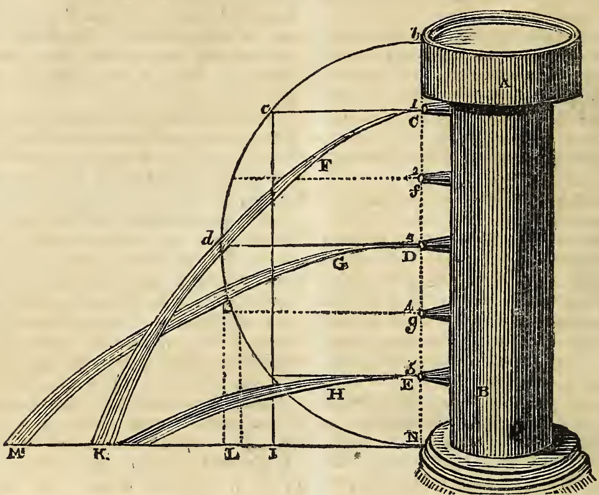
In the case of mercury, glass either repels the fluid, or attracts it less than its particles attract one another. Hence, the convexity of the surface that terminates the column, and the depression of that surface below the natural level.

FLUIDS ISSUING THROUGH APERTURES IN THE BOTTOM OR SIDES OF VESSELS.

The velocity with which water spouts out at a hole in the side or bottom of a vessel, compared with the velocity with which it spouts out at another of a different depth, is as the square root* of the depths or distance of the holes below the surface of the water. For, in order to make double the quantity of a fluid run through one hole as through another of the same size, it will require four times the pressure of the other, and therefore must be four times the depth of the other below the surface of the water: and for the same reason, three times the quantity running in an equal time through the same form and size of hole, must run with three times the velocity, which will require nine times the pressure; and consequently must be nine times as deep below the surface of the

* The square root of any number is that which, being multiplied by itself, produces the said number. Thus, 2 is the square root of 4, and 3 is the square root of 9: for 2 multiplied by 2 produces 4, and 3 multiplied by 3 produces 9, &c.

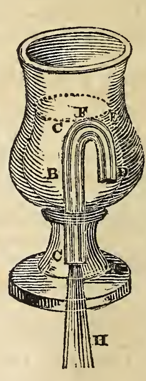
fluid: and so on. To prove this by experiment, let two pipes, as C and *g*, of equal sized bores, be fixed into the side of the vessel A B, as in the following figure,



the pipe *g* being four times as deep below the surface of the water at *b* in the vessel, as the pipe C: and whilst these pipes run, let water be constantly poured into the vessel, to keep the surface still at the same height. Then, if a cup that holds a pint be so placed as to receive the water that spouts from the pipe C, and at the same moment a cup that holds a quart be so placed as to receive the water that spouts from the pipe *g*, both cups will be filled at the same time by their respective pipes.

The horizontal distance to which a fluid will spout from a horizontal pipe, in any part of the side of an upright vessel, below the surface of the fluid, is equal to twice the length of a perpendicular to the side of the vessel, drawn from the mouth of the pipe to a semicircle described upon the altitude of the fluid: and therefore, the fluid will spout to the greatest distance possible from a pipe whose mouth is at the centre of the semicircle; because a perpendicular to its diameter (supposed parallel to the side of the vessel) drawn from that point, is the longest that can possibly be drawn from any part of the diameter to the circumference of the semicircle. Thus, if the vessel A B (see above figure) be full of water, and the horizontal pipe D be in the middle of its side, and the semicircle N *e d c b* be described upon D as a centre, with the radius or semidiameter D N, or D *b*, the perpendicular D *d* to the diameter N D *b* is the longest that can be drawn from any part of the diameter to the circumference N *e d c b*. And if the vessel be kept full, the jet G will spout from the pipe D, to the horizontal distance N M, which is double the length of the perpendicular D *d*. If two other pipes, as C and E, be fixed into the side of the vessel at equal distances above and below the pipe D, the perpendiculars, C *c* and E *e*, from these pipes to the semicircle, will be equal; and the jets F and H spouting from them will each go to the horizontal distance N K; which is double the length of either of the equal perpendiculars C *c* or E *e*.

Let a hole be made quite through the bottom of the cup A, as in the following figure,



and the longer leg of the bended syphon D E B G be cemented into the hole, so that the end D of the shorter leg D E may almost touch the bottom of the cup within. Then, if water be poured into this cup, it will rise in the shorter leg by its upward pressure, excluding the air all the way before it through the longer leg: and when the cup is filled above the bend of the syphon at F, the pressure of the water in the cup will force it over the bend of the syphon; and it will descend in the longer leg C B G, and run through the bottom, until the cup be emptied.

This is generally called *Tantalus's cup*, and the legs of the syphon in it are almost close together; and a little hollow statue or figure of a man, is sometimes put over the syphon to conceal it; the bend E being within the neck of the figure as high as the chin—so that poor thirsty *Tantalus* stands up to the chin in water, imagining it will rise a little higher, and he may drink; but instead of that, when the water comes up to his chin, it immediately begins to descend, and so, as he cannot stoop to follow it, he is left as much pained with thirst as ever.

Having now illustrated some of the facts respecting the discharge of water through apertures in the bottom or sides of vessels, by means of the foregoing figures, we shall here give some rules for calculating the velocity and quantity of water discharged from apertures of a given size and depth, which we shall further illustrate by arithmetical examples.

The *velocity* with which a fluid issues through an orifice in the bottom or side of a vessel, is equal to that which a heavy body would acquire by falling from the level of the surface to the level of the orifice. Thus: suppose the depth of an orifice in the side of a vessel containing water to be 4 feet below the surface of the water, and that the velocity acquired by a falling body, in one second of time, is equal to 32 feet, required the velocity with which the water issues from the orifice. Here, 32 multiplied by 4 is 128, which being doubled is 256, the square root of which is 16 feet, the velocity that a heavy body would acquire in falling 4 feet; consequently the water will issue with a velocity of 16 feet per second.

If the velocity with which the fluid issues from the orifice were turned directly upward, it would carry it to the level of the surface of the fluid.

The *quantity* of water that issues in one second through a given orifice, is equal to a column of water having the area of the orifice for its base, and the velocity with which the fluid issues for its altitude.

Thus, if the area of the orifice be 2 square inches, and the velocity with which it issues be 16 feet per second, then the quantity of water which issues in one second is 192, (the inches in 16 feet,) multiplied by 2, or 384 cubic inches.

It is found, however, when the experiment is made, that the quantity is not so great as this rule makes it, particularly when the orifice is small, for the vein of water that issues through the orifice suffers a contraction, by which its section has been ascertained to be diminished in the ratio of 5 to 7 nearly. Therefore, $\frac{5}{7}$ of the above result must be taken as the true quantity discharged.

We may also remark, that some writers suppose that water issues only with the velocity that would be acquired by a body falling through half the depth of the fluid. According to some very accurate experiments of Bossut, the actual discharge through a hole made in the side or bottom of the vessel, is to the theoretical as 1 to ·62, or nearly as 8 to 5. The theoretical discharge, when computed, must, therefore, be diminished in this ratio to have the true one according to this philosopher.

If the water issues, not through an aperture in the side or bottom of the vessel, but through a pipe from 1 to 2 inches in length, inserted in the aperture, the contraction of the vein is prevented, and the actual discharge becomes to the theoretical, as 8 to 10, or 4 to 5. In this way, therefore, the discharge is increased nearly in the ratio of 4 to 3.

Water thrown up in a perpendicular jet ought to ascend to the height of the reservoir; but on account of the resistance of the air, the friction of the pipe, &c. it always falls short of that height; and it is found by experiment, that the difference between the heights of the jets and of the reservoirs, are as the squares of the heights of the jets themselves.

The water ascends highest when the jet is not quite perpendicular; when it is perpendicular, the ascent is obstructed by the water falling back on the ascending column.

The height to which the water rises in the jet, is called the *height of the effective head.*

Miscellaneous Subjects.

BIOGRAPHICAL MEMOIR OF EUCLID.

Euclid was a native of Megara, and founder of the Megaric or Eristic sect, and was distinguished by his subtle genius, and early application to the study of philosophy. Having acquired some knowledge of the art of disputation from the writings of Parmenides, he was induced, by the fame of Socrates, to remove from Megara to Athens, where he became the auditor and disciple of this eminent philosopher. Notwithstanding the terror of the Decree, which enacted, "That any inhabitant of Megara, who should be seen at Athens, should forfeit his life," he frequently came to Athens by night, from the distance of about twenty miles, concealed in a long female cloak and veil, to visit his master. He also frequently engaged in the business and disputes of the civil courts, by which proceeding he offended Socrates, who despised forensic contests; and this circumstance seems to have occasioned a separation between them. Afterwards he put himself at the head of a school in Megara, where his chief employment was to teach the art of disputation. Although he was much addicted to vehement debates, he possessed so great a command of temper, that in a quarrel with his brother, who said to him, "Let me perish if I be not revenged upon you;" Euclid replied, "And let *me* perish, if I do not subdue your resentment by forbearance, and make you love me as much as ever."

Euclid, known to every well-educated youth, by his "Elements," was, according to the testimony of Pappus and Proclus, a native of Alexandria, in Egypt, where he flourished and taught the mathematics in the reign of Ptolemy Lagus, about 300 years before Christ. His was the first mathematical school in that far-famed city, where, till its conquest by the Saracens, most of the eminent mathematicians were either born or studied. To Euclid, and to those immediately educated by him, the world has been indebted for Eratosthenes, Archimedes, Apollonius, Ptolemy, &c. "The Elements," to which we have already referred, are not to be wholly attributed to Euclid; many of the invaluable truths and demonstrations contained therein were discovered and invented by Thales, Pythagoras, Eudoxes, and others; but Euclid was the first who reduced them to regular order, and who probably interwove many theorems of his own, to render the whole a complete and connected system of geometry. "The Elements" consist of fifteen books, but the last two are suspected to have been written 200 years after Euclid's death, by Hypsicles of Alexandria. The best edition published in this country is that printed at Oxford, in folio, in 1703; but the most common edition in our schools is that by the late learned Dr. Simson. Euclid is said to have been a person of agreeable and pleasing manners, and admitted to habits of friendship and familiarity with king Ptolemy, who once demanded of the mathematician if he could not direct him to some shorter and easier way of acquiring a knowledge of geometrical truths than that which he had exhibited in his "Elements;" to which Euclid replied, that "there was no royal road to geometry."

Euclid, as a writer on music, has ever been held in the highest estimation by all men of science who have treated of harmonics, or the philosophy of sound. As Pythagoras was allowed by the Greeks to have been the first who found out musical ratios, by the division of a monochord, or single string, a discovery which tradition only had preserved, Euclid was the first who wrote upon the subject, and reduced these divisions to mathematical demonstration.

His "Elements" were first published at Basil in Switzerland, 1533, by Simon Grynaeus, from two MSS; the one found at Venice, and the other at Paris. His "Introduction to Harmonics," which in some MSS was attributed to Cleonidas, is in the Vatican copy given to Pappus: Meibomius, however, accounts for this, by supposing those copies to have been only two different MS editions of Euclid's work, which had been revised, corrected, and restored from the corruptions incident to frequent transcription by Cleonidas and Pappus, whose names were, on that account, prefixed. It first appeared in print with a Latin version, in 1498, at Venice, under the title of "Cleonidæ Harmonicum Introductorium,"—who Cleonidas was, neither the editor, George Valla, nor any one else, pretends to know. It was John Pena, a mathematician in the service of the king of France, who first published this work at Paris, under the name of Euclid, in 1557. After this it went through second editions with his other works.

His "Section of the Canon" follows his "Introduction;" it went through the same hands and the same editions, and is mentioned by Porphyry, in his Commentary on Ptolemy, as the work of Euclid. This tract chiefly contains short and clear definitions of the several parts of Greek music, in which it is easy to see, that mere *melody* was concerned; as he begins by telling us, that the science of harmonics considers the nature and use of melody, and consists of seven parts:—sounds, intervals, genera, systems, keys, mutations, and melopocia; all which have been severally considered in the dissertation.

Of all the writings upon ancient music, that are come down to us, this seems to be the most correct and compressed: the rest are generally loose and confused; the authors either twisting and distorting every thing to a favourite system, or filling their books with metaphysical jargon, with Pythagoric dreams and Platonic fancies, wholly foreign to music. But Euclid, in this little treatise, is, like himself, close and clear; yet so mathematically short and dry, that he bestows not a syllable more upon the subject than is absolutely necessary.

His object seems to have been the compressing into a scientific and elementary abridgement, the more diffused and speculative treatises of Aristoxenus. He was the D'Alembert of that author, explaining his principles, and, at the same time, seeing and demonstrating his errors. The musical writings of Rameau were diffused, obscure, and indigested; but M. D'Alembert, extracting the essence of his confused ideas, methodised his system of a *fundamental base*, and compressed, into the compass of a pamphlet, the substance of many volumes.

According to Dr. Wallis, Euclid was the first who demonstrated that an octave is somewhat less than *six whole* tones; and this he does in the 14th theorem of his "Section of the Canon." In the 15th theorem he demonstrates, that a fourth is less than two tones and a half, and a fifth less than three and a half; but though this proves the necessity of a temperament upon fixed instruments, where one sound answers several purposes, yet he gives no rules for one, which seems to furnish a proof that such instruments were at least not *generally* known or used by the ancients.

What Aristoxenus called a *half tone*, Euclid demonstrated to be a smaller interval, in the proportion of 256 to 243. This he denominated a *limma*, or *remnant*; because giving to the *fourth*, the extremes of which were called *soni stabiles*, and were regarded as fixed and unalterable, the exact proportion of 4 to 3; and, taking from it two major tones $\frac{8}{9} \times \frac{8}{9}$, the limma was all that remained to complete the diatessaron. This division of the diatonic genus being thus, for the first time, established upon mathematical demonstration, continued in favour, says Dr. Wallis, for many ages.

HEIGHTS OF THE PRINCIPAL MOUNTAINS IN THE WORLD, EXPRESSED IN ENGLISH FEET.

Those marked with the letter B have been determined by the barometer; and those marked with the letter G, by geometrical operations

Snæ Fiall Jokul, on the north-west point of Iceland	4,558	B
Hekla, volcanic mountain in Iceland	3,950	G
Pap of Caithness	1,929	
Ben Nevis, Inverness-shire	4,380	B
Cairngorm, Inverness-shire	4,080	B
Ben Lawers, Perthshire	4,015	B
Ben More, Perthshire	3,870	B
Schihallien, Perthshire	3,281	G
Ben Ledi, Perthshire	3,009	B
Ben Lomond, Stirlingshire	3,240	B
Lomond Hills, east & west, Fifeshire,	1,466 & 1,721	G
Soutra Hill, on the ridge of Lammer muir,	1,716	G
Carnethy, highest point of the Pentland ridge	1,700	
Tintoc, Lanarkshire	1,720	B
Leadhills, the house of the Director of the Mines	1,564	
Queensbery Hill, Dumfries-shire	2,259	G
Dunrigs, Roxburghshire	2,408	G
Elden Hills, near Melrose, Roxburghshire,	1,364	G
Crif Fell, near New Abbey, in the Stewartry of Kirkcudbright	1,831	G
Goat Fell, in the Isle of Arran	2,950	B
Paps of Jura, south and north, in Argyllshire	2,359 & 2,470	
Snea Fell, in the Isle of Man	2,004	G
Macgillicuddy's Reeks, county Kerry	3,404	
Mourne Mountains, county of Down	2,500	
Helvellyn, Cumberland	3,055	G
Skiddaw, Cumberland	3,022	G
Saddleback, Cumberland	2,787	G
Whernside, Yorkshire	2,384	G
Ingleborough, Yorkshire	2,361	G
Shunnor Fell, Yorkshire	2,329	G
Snowdown, Caernarvonshire	3,571	G
Cades Idris, Caernarvonshire	2,914	G
Beacons of Brecknock	2,862	G
Plynlimmon, Cardiganshire	2,463	G
Penmaen Mawr, Caernarvonshire	1,540	G
Malvern Hills, Worcestershire	1,444	G
Cawsand Beacon, Devonshire	1,792	G
Rippon Tor, Devonshire	1,549	G
Brocken, in the Hartz forest, Hanover	3,690	
Schneekopf, in Silesia	4,950	
Priel, in Austria	6,565	
Peak of Lomnitz, in the Carpathian ridge,	8,640	
Mont Blanc, Switzerland	15,646	G
Village of Chamouni, below Mont Blanc,	3,367	G
Jungfrauhorn, Switzerland	13,730	
St. Gothard, Switzerland	9,075	
Hospice of the Great St. Barnard, on the passage to Italy	8,040	B
Village of St. Pierre, on the road to Great St. Barnard	5,338	B
Passage of Mont Cenis	6,778	B
Ortler Spitze, in the Tyrol	15,430	
Rigiberg, above the lake of Lucerne	5,408	
Dole, the highest point of the chain of Jura,	5,412	B
Mont Perdu, in the Pyrenées	11,283	
Loneira, in the department of the high Alps	14,451	
Peak of Arbizon, in the department of the high Pyrenées	8,344	
Puy de Dome, in Auvergne	5,197	
Summit of Vaucluse, near Avignon	2,150	
Soracte, near Rome	2,271	G
Monte Velino, in the kingdom of Naples,	8,397	G
Mount Vesuvius, volcanic mountain near Naples	3,978	
Ætna, volcanic mountain in Sicily	10,963	B
St. Angelo, in the Lipari islands	5,260	
Top of the Rock of Gibraltar	1,439	B
Mount Athos, in Rumelia	3,353	
Diana's Peak, in the Island of St. Helena,	2,692	
Peak of Teneriffe, one of the Canary Islands	12,358	B
Ruivo Peak, the highest point in the island of Madeira	5,162	
Table Mountain, near the Cape of Good Hope	3,520	
Chain of Mount Ida, beyond the plain of Troy	4,960	
Chain of Mount Olympus, in Anatolia	6,500	
Italitzkoi, in the Altaic chain	10,735	
Awatsha, volcanic mountain in Kamtchatka	9,600	
Taganai, in the Uralian chain	4,912	
The Volcano, in the Isle of Bourbon	7,680	
Ophir, in the centre of the Island of Sumatra	13,842	

St. Elias, on the western coast of North America	12,672	
Chimborazo, highest summit of the Andes,	21,440	B
Antisana, volcanic mountain in the kingdom of Quito	19,150	B
Cotopaxi, volcanic mountain in the kingdom of Quito	18,890	B
Tonguragua, volcanic mountain near Riobomba, in Quito	16,579	B
Rucu de Pichincha, in the kingdom of Quito	15,940	B
Heights of Assuay, the ancient Peruvian road	15,540	B
Peak of Orizaba, volcanic mountain east from Mexico	17,390	G
Lake of Toluca, in the kingdom of Mexico	12,195	B
City of Quito	9,560	B
City of Mexico	7,476	B
Silla de Caraccas, part of the chain of Venezuela	8,640	B
Blue Mountains, in the Island of Jamaica,	7,431	
Pelée, in the Island of Martinique	5,100	
Morne Garou, in the Island of St. Vincents	5,050	
Mount Misery, in the Island of St. Christophers	3,711	

MOUNTAINS IN THE EAST INDIES.

Himalay, or White Mountains	26,860
Yamunavaben, or Jamautri	25,500
Supposed Dhaibun	24,740

ON THE STUDY OF OPTICS.

To the Editor of the Artisan.

Sir.—Perceiving that part of your valuable publication is devoted to miscellaneous subjects connected with the Arts and Sciences, I have taken the liberty of sending you a short article on the Study of the pleasing and highly useful science of Optics. Should you think proper to insert it in any of your succeeding numbers, it may, perhaps, be the means of turning the attention of some of your ingenious readers to this interesting subject.

I have frequently felt no small surprise, that a science so useful and entertaining as Optics should be so much neglected as it is at the present day, while many other branches of practical and scientific knowledge are so eagerly cultivated, and held in such high estimation. I believe there has scarcely been a discovery, or even an improvement, made, either in the theoretical or practical part of optics, since the days of the celebrated Dolland, if we except the *camera lucida* by Dr. Wolaston, and the *kaleidoscope* by Dr. Brewster. But it may, perhaps, be observed, that it does not follow, because no discoveries or improvements, except those just mentioned, have been made in this branch of knowledge, that the cultivation of it is neglected; since it may possibly be one of those sciences which has already arrived at perfection. For myself, I confess, I have yet to learn what science has attained to this stage. I am not aware of any; and am of opinion, that none offers so fair a prospect for discovery, or is so susceptible of improvement, as that of optics. Although we know some of the laws which light obeys, in passing from one body to another, and even some of its effects upon certain substances, we are completely ignorant of its nature. And who will say, that all its *effects* are already known?

The practical part of the formation and combination of glasses is capable of great improvement, though very few efforts have of late been made to effect it. It would be trifling with the time of your readers to attempt any proof of so obvious a truism as the former part of this assertion; but it may, perhaps, be necessary to advance some arguments in support of the latter, as the truth of it is more likely to be called in question. Before adducing these, I beg leave to observe what criteria I consider necessary for deciding upon its correctness. The popularity of any branch of physical knowledge can only be judged of by the following circumstances: the number of books published on the subject—of persons employed in teaching it—of instruments manufactured for its cultivation and application—and of the various discoveries made in it. And it is sufficiently easy to show, that the application of any of these tests will prove optics not to be at present a popular branch of knowledge. We very seldom hear of a book making its appearance, either on the theory or practice of this science: and, amid all the advertising of lecturers, and the puffing of teachers, it is scarcely ever adverted to. As to the demand for optical instruments, it is only necessary to refer individuals to their respective circles of acquaintance, to convince them, how small is the number in general use. And I have already had occasion to remark, how very limited has been the extent of discoveries in this science within the last thirty years.

The *utility* of optics is so universally acknowledged, that it is almost superfluous to enlarge upon it. I may, however, be permitted to mention one or two facts, to shew the advantages which have already resulted to mankind from its cultivation.

The formation and combination of glasses, according to the laws of optics, have been the means of exhibiting to us wonders which could never have been even anticipated without them. The ancients had no idea of the existence of objects which the invention of the microscope and the telescope have made known to us. Who would have imagined, for example, that a single drop of liquid contains more animals than there are men, women, and children, on the surface of the whole earth?* Or, who could have supposed, before the discovery of the telescope, that the planet Saturn was surrounded by a broad luminous ring?—that the face of the moon was diversified with mountains and vallies, and that the milky way was, to use the language of the poet, "powdered with stars?"

It is to the discoveries which have been made in optics that astronomy, and consequently geography and navigation, have been indebted for the greatest part of their improvements. To optics the art of drawing and perspective likewise owe many of the fundamental principles upon which they depend. But had this science rendered no other service to mankind than that of supplying them with the simple but highly valuable article of *spectacles*, it would have ample claims on their gratitude and regard. This beautiful and beneficial application of glasses may indeed be said to give eyes to the blind. And, were we even to discard from the question every consideration of utility, the intrinsic pleasure and enjoyment arising from the pursuit of this interesting science, should recommend it to our study and attention, and excite regret in the mind of every scientific person, to see it falling into undeserved comparative neglect.

Oculus.

* Though this is generally stated to be the case by writers on the microscope, yet it would be difficult to prove if in a satisfactory manner.—Ed.

SINGULAR APPLICATION OF HEAT.

Some years ago it was observed, at the *Conservatoire des Arts et Metiers* at Paris, that the two side-walls of a gallery were receding from each other, being pressed outwards by the weight of the roof and floors. Several holes were made in each of the walls, opposite to one another, and at equal distances, through which strong iron bars were introduced, so as to traverse the chamber. Their ends outside of the wall were furnished with thick iron discs, firmly screwed on. These were sufficient to retain the walls in their actual position. But to bring them nearer together would have surpassed every effort of human strength. All the alternate bars of the series were now heated at once by lamps, in consequence of which they were elongated. The exterior discs being thus freed from contact of the walls, permitted them to be advanced farther, on the screwed ends of the bars. On removing the lamps, the bars cooled, contracted, and drew in the opposite walls. The other bars became in consequence loose at their extremities, and permitted their end plates to be further screwed on. The first series of bars being again heated, the above process was repeated in each of its steps. By a succession of these experiments they restored the walls to the perpendicular position; and could easily have reversed their curvature inwards, if they had chosen. The gallery still exists, with its bars, to attest the ingenuity of its preserver, M. Molard.

SOLUTION OF QUESTIONS.

To the Editor of the Artisan.

Sir.—In the *second* Number of your valuable publication, I have observed a Philosophical Query, respecting the velocity with which a boat passes over water at different depths. I have therefore taken the liberty of sending you my opinion of the cause which occasions the difference of velocity which your correspondent, Mercator, has stated to exist.

I apprehend, that a boat in proceeding along a canal or smooth water, must, in every boat's length of her course, move out of her way a body of water equal in bulk to the room her bottom takes up in the water; that the water so moved, must pass on each side of her, and under her bottom, to get behind her; and that, if the passage under her bottom be straightened by the shallows, more of that water must pass by her sides, and with a swifter motion, which will retard her, as moving the contrary way; or that the water becoming lower behind the boat than before her, she will be pressed back by the weight of its difference in height, and her motion is retarded by having that weight constantly to overcome.

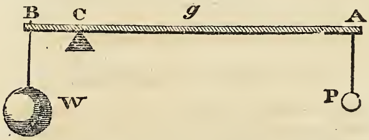
This, Sir, I consider to be the true cause, but the quantity of difference I am unable to state, having never made any experiments to ascertain it; but having often occasion to be on the River Thames, I lately enquired of several watermen, whether they were sensible of any difference in rowing over shallow or deep water, I found them all agree in the fact, that there was a very great difference, but they differed widely in expressing the quantity of the difference; some supposing it was equal to a mile in six, others to a mile in three, &c. As I do not recollect to have met with any mention of this matter in any philosophical book, and conceiving, that if the difference should really be great, it might be an object of consideration in many projects now on foot for digging new navigable canals in this country.

Aquatus.

To the Editor of the Artisan.

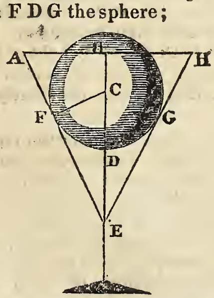
SIR.—Having observed two Philosophical questions (by Peter Plus) in the second number of the Artisan, of which the solution is required, I have amused myself by undertaking this task; and, as I believe I have accomplished it, I here send you what I conceive to be an accurate solution of both questions. MOSES MINUS.

Example 1:—Let x represent A C, the longer arm of the lever, A B;



and let $a = $ B C, or (1), W $= 45$, and P $= 2$, then $x + a =$ A B, the whole length of the lever; and as it is homogeneous, $\frac{x+a}{2}$, or the middle of the lever will be its centre of gravity, and $\frac{x-a}{2}$ will be the distance of the centre of gravity from the *fulcrum*, at C; then from the property of the lever $Px + \frac{x^2 - a^2}{2} = aW$, or $Px + x^2 - a^2 = 2aW$, and this quadratic reduced, gives $x = \sqrt{2aW + a^2 + P^2} - P$, or $x = 7{\cdot}7468$ in this case, or the distance of the power from the fulcrum; and $x + 1 = 8{\cdot}7468$ the whole length of the lever in feet, or its weight in pounds.

Example 2:—Let A E H represent the glass, and F D G the sphere;



the triangle A E B, and C E F are equiangular, therefore, B A : A E :: F C : C E, that is, $2\frac{1}{2} : (2\frac{1}{2}^2 + 6^2)^{\frac{1}{2}} :: 2 : 5{\cdot}2$, and B C $=$ B E $-$ E C $= 6 - 5{\cdot}2 = {\cdot}8$; B D $= 2{\cdot}8$ the height of the segment immersed, and its content is $(3 \times (4 - 2{\cdot}8) \times 2) \times 2{\cdot}8^2 \times {\cdot}5236 = 26{\cdot}272$ cubic inches, the answer.

This question was also answered, nearly in the same manner, by John Boronesphilosmathematicus, Manchester; and by Mr. John Stephens, somewhat differently, though not quite so accurately: for he makes the answer 26·7036 cubic inches, which is too great by ·4316 of an inch.

Mr. Richard Graham, teacher of mathematics, Ranelagh-street, Liverpool, also gave a very neat solution; but it did not arrive in time for publication in the present Number.

A correspondent, who signs Caldwell, Warrington, also sent us a solution of this question; but it was not altogether correct.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR.—Please to insert the following question in one of your succeeding numbers, which will very much oblige your obedient servant, RICHARD GRAHAM.
Ranelagh-street, Liverpool.

My brewer requests me to inform him, what thickness a solid inch of glass must be blown to contain an ale gallon, or 282 cubic inches?

To the Editor of the Artisan.

SIR.—I take the liberty of sending you the following mathematical question, which I will thank you to insert in an early number, which will oblige,

JOHN BORONESPHILOSMATHEMATICUS.

On December 24, 1823, at night, the altitude of Pollux was observed, and that of the middle star in Orion's belt,—their difference $= 6^\circ\ 35'$: also at the same time the difference of their azimuths, from the north, $= 51^\circ$. Required the latitude of the place of observation?

To the Editor of the Artisan.

SIR,—Can you, or any of your readers, inform me if *all dry* solid bodies become *hot* by friction, or rubbing? I should also be happy to know, if any philosophical reason can be given why liquids are not heated, or have their temperature raised by agitation.—I am, Sir, &c.

AQUATUS.

To the Editor of the Artisan.

SIR.—Having often heard of the temperature of bodies being *eight* hundred, *nine* hundred, and a *thousand* degrees of Fahrenheit's scale, I should be obliged to you, or any of your philosophical correspondents, to inform me, by what instrument these temperatures are measured; and what is the most accurate way of measuring temperatures between *seven* hundred and a *thousand* degrees of the above scale.

A MECHANIC.

SIR HUMPHRY DAVY BAR^{T}

PRESIDENT OF THE ROYAL SOCIETY.

Pub. 1824, by Hodgson & C^{o} 10 Newgate St.

MEMOIR OF SIR HUMPHRY DAVY, BART.

The most gratifying theme to which the pen of the biographer, or even the pencil of the artist, can be devoted, is the handing down to posterity correct delineations of extraordinary men; who, at different periods and in all ages have, like meteors, burst upon the world, shedding new light upon science, adding fresh beauty to literature, and invigorating and improving the morals of mankind:—To record these, forms the most delightful task of the historian.

The object of these memoirs has, perhaps, done more for the *chemical* world than any man who has preceded him; but whilst we thus pay a tribute to the man of scientific research, we must not forget that Sir Humphry Davy combines both the scholar and the philosopher; and although apparently devoted to the mutation of forms in the Laboratory, he has not been unmindful even of the variation of the Muses, to which the pages of the "Annual Anthology," now discontinued, bear ample testimony, in the shape of some very spirited poetical effusions, said to have emanated from his pen ere he was ten years old; an amusement he pursued to a much later period.

Descended from an ancient family in Cornwall, he was born at Penzance, near the Land's End, in the year 1779, on the 17th of December; at the grammar schools of which place and of Truro, he received the rudiments of his education, and gave early proofs of those masculine powers, which have since procured him distinguished honours from his sovereign, and an imperishable reputation among men.

Having originally intended to pursue the medical profession, he resided some time at Penzance, with a friend of his maternal grandfather, a Mr. Tomkins, who was a surgeon of considerable eminence, and from whom he derived both intellectual and professional improvement. But intending to graduate at Edinburgh, he at length became the pupil of Mr. Borlase, who also resided at Penzance, a gentleman of great intelligence, both as a surgeon and a scholar; under whom, by steadily pursuing a methodical system of reading, previously determined upon, he became, at the age of eighteen, familiar with the science of Botany, Anatomy, Physiology, Mathematics, Metaphysics, Natural Philosophy, and Chemistry; to the latter of which his genius had decidedly devoted him.

His first discovery in the *arcana* of science, was of great importance—no less than that sea-weed rendered the air contained in water pure, by the same agency that vegetables deprive atmospheric air of its noxious qualities. This at once marked him as a man of unwearied research, and he was looked up to as one from whose perseverance much was to be expected. This fact he made known to Dr. Beddoes, with whom he had become intimate, and who was, at that time, endeavouring to form an establishment, in order to ascertain, experimentally, the power of gas as applied to the cure of human diseases.—Dr. Beddoes was so much pleased, that he invited Davy, then under twenty, to join him in his pursuit; to which the latter consented, conditionally—that the whole of the experiments should be under his immediate control. This being conceded, he relinquished his predetermination to graduate at Edinburgh, and removed to Bristol, where Dr. Beddoes then resided: here he spent some considerable time, and contracted an intimacy with Davies Giddy, Esq. who has since taken the name of Gilbert, a gentleman well known to the scientific world; who being also an admirer of the young experimentalist, determined him, by his advice, to continue a career, which he has since run with so much honour to himself, and substantial advantage to the world—of which the safety lamp may be fairly quoted as an instance. Mr. W. Clayfield frequently assisted him in his labours, during his residence at Bristol, where his indefatigable zeal, in the pursuit of his favourite science, brought to light the respirability of the nitrous oxide. Soon after, he published his work, entitled, "Researches Chemical and Philosophical," in which he embodied the result of his experiments in gaseous matter. This publication procured him the Professor's Chair in Chemistry, at the Royal Institution, by introducing him to the notice of Count Rumford, who deeply interested himself to procure Mr. Davy's election. From this period we find him in the very nucleus of scientific information, with ample facilities to extend his inquiries into the secrets of nature. Domiciliated in the British metropolis, at the very head of a liberal institution, he had the command of a well-appointed laboratory, a complete electrical apparatus, with the various scientific instruments belonging to that establishment; thus his means were more perfect than he had hitherto found them, and he bent the whole force of his genius on chemical science. He carefully examined, but without making any new discovery, the vegetable substance called *Tannin*.

In 1803, although he had not yet made those discoveries which have since spread his fame upon eagle wings, not only in the estimation of his own countrymen, but in that of the whole world, he was chosen a member of the Royal Society; in 1805, he was made a member of the Royal Irish Academy; and, in 1806, he became the Secretary to the Royal Society, and was in correspondence with the most eminent chemists and literati of both hemispheres. His experiments with the galvanic battery had now, for a considerable period, engrossed his attention; and it was at this time also, he delivered his Bakerian lectures before the Royal Society, the first of which made known some highly important phenomena of the chemical actions of electricity, especially relating to alkalis and acids.

In 1807, he communicated his grand discoveries of the metallic bases of potash and soda, which he called *potassium* and *sodium*; and at the same epoch, by like experiments, he decomposed and ascertained the metallic bases of other substances; after which, he demonstrated, that oxmuriatic acid was not, as it has been supposed, a compound, but a simple substance, and he called it CHLORINE.

At first, some of the French chemists rejected his hypothesis, that *oxygen* was one of the alkaline principles; nor would they allow *potassium* and *sodium* to be any thing but *hydrates*; however they were ultimately obliged to acknowledge its correctness. For the honour of science it ought never to be forgotten, that although England and France then waged a war of unexampled inveteracy, the French Institute awarded the prize to our recondite countryman. This was no less honourable to Napoleon, who was then at the head of the Institute, than that he should also send him a sum of money, and further grant him free passports, so that he might travel wherever he listed, through the dominions then under his control; thus the rancour of belligerancy bowed to the superior genius of Sir Humphry, then Mr. Davy.

In 1811, Mrs. Apreece, an amiable and accomplished widow lady, of considerable fortune, became the object of Mr. Davy's solicitude and affection; and in the following year, (a short period previous to which happy event, he had the honour of knighthood conferred upon him by his present Majesty, then Prince Regent,) he led that lady to the hymeneal altar.

In a series of lectures began about the same time, and which he continued for three years before the Board of Agriculture, Sir Humphry particularly impressed upon their minds the dependance of that branch of British wealth, upon the science of chemistry. In 1814, he was chosen Vice-President of the Royal Institution, and a corresponding member of the French Institute. In 1815, at the particular request of a committee of gentlemen formed at Sunderland, in consequence of the innumerable accidents which arose from the explosion of fire damps in the coal mines, and to provide, if possible, a remedy, Sir Humphry examined most of the large collieries in the north, an undertaking of equal importance, both to science and humanity; and, after numerous experiments to ascertain the qualities of the exploding gas, it ended in the invention of his *Safety Lamp*. This effort of his indefatigable genius was considered so eminently useful, that the coal owners of the Tyne and Wear presented him with a service of plate, estimated at the value of 2,000*l*. The originality of this invention was for a time disputed: but it is now generally allowed.

In 1817, Sir Humphry was created a baronet, and elected an Associate of the Royal Academy. During the two following years, he travelled to Italy, where he analyzed the colours used by the ancients in their paintings; and examined the manuscripts found in Herculaneum. These he thought were not completely carbonized, but closely adhered together by a substance chemically produced during the long period they had remained buried, and which might be dissolved: but not more than one hundred out of nearly thirteen hundred afforded any likelihood of their being successfully unrolled. In 1820, he returned to his native shores, about which period, Sir Joseph Banks, the late venerable President of the Royal Society, dying, Sir Humphry Davy and Dr. Wollaston were looked upon as the most eligible members to fill the vacancy. Dr. Wollaston, however, refused to stand in the way of his friend; and, notwithstanding he was opposed by Lord Colchester, who was himself proposed without his own sanction, the disputed chair was given to Sir Humphry Davy, by a majority of nearly two hundred; nor shall we detract from the merits of the defunct President, by adding, that it has never been so ably filled, since the days of that constellation of science, Sir Isaac Newton, as it is by the present noble occupant.

The last important discovery for which the world is indebted to him, is the prevention of the corrosion and decay of copper used for lining the bottoms of ships, by a very simple method, and which he communicated to the Royal Society. The cause of the corrosion, he said, was a weak chemical action constantly exerted between the saline contents of the sea-water and the copper: and he recommends the application of a very small surface of tin, or other oxydizable metal, which any where in contact with a large surface of copper, renders it so negatively electrical, that sea-water has no action upon it; and a little mass of tin brought in communication by a wire with a large plate of copper, entirely preserves it. This discovery, by order of the Lords of the Admiralty, is now coming into actual practice on board ships of war. The works of which Sir Humphry is the author, are, Chemical and Philosophical Researches; Elements of Chemical Philosophy; Elements of Agricultural Chemistry; and divers pamphlets: besides a considerable number of papers published in the Philosophical Transactions, &c.

August 1825

PNEUMATICS.

After the full description now given of the *Air Pump*, we shall show how a number of interesting and important experiments may be performed by it, which will afford the most convincing and satisfactory proofs that can be given of the *weight*, *elasticity*, and other mechanical properties of the air. And as many persons may not have it in their power, either to perform, or witness the performance, of these experiments, we shall endeavour to make them as interesting as possible, by stating the important facts which they have been the means of making known to us.

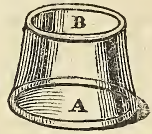
EXPERIMENTS WITH THE AIR PUMP.

To show the weight or pressure of the air.

1. Procure a thin bottle or Florence flask, whose contents are exactly known in cubic inches, then let a cap, with a valve fastened over it, be nicely fitted to the mouth of the flak. Screw the neck of this cap into the hole *i* of the pump-plate; then, having exhausted the air out of the flask, and taken it off from the pump, let it be suspended at one end of a balance, and nicely counterpoised by weights in the scale at the other end: this done, raise up the valve with a pin, and the air will rush into the flask with an audible noise; during which time the flask will descend, and pull down that end of the beam. When the noise is over, put as many grains into the scale at the other end as will restore the equilibrium; and they will shew exactly the weight of the quantity of air which has got into the flask, and filled it. If the flask holds an exact quart, it will be found that 17 grains will restore the equipoise of the balance, when the quicksilver stands at 29½ inches in the barometer: which shews, that when the air is at a mean rate of density, a quart of it weighs 17 grains; it weighs more when the quicksilver stands higher: and less when it stands lower.

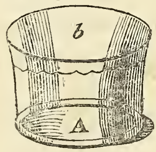
2. Place the small receiver O, which is within the large one already on the pump-plate of the air pump, over the hole *i*, in the pump-plate, and upon exhausting the air, the receiver will be fixed down to the plate by the pressure of the air on its outside, which is left to act alone, without any air in the receiver to act against it; and this pressure will be equal to as many times 15 pounds as there are square inches in that part of the plate which the receiver covers; which will hold down the receiver so fast, that it cannot be got off, until the air be let into it by turning the cock *k*, and then it becomes loose.

3. Set the little glass AB,



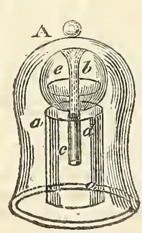
(which is open at both ends) over the hole *i*, upon the pump-plate LL, and put your hand close upon the top of it at B; then upon exhausting the air out of the glass, you will find your hand pressed down with a great weight upon it, so that you can hardly release it, until the air be re-admitted into the glass by turning the cock *k*; which air, by acting as strongly upward against the hand as the external air acted in pressing it downward, will release the hand from its confinement.

4. Having tied a piece of wet bladder *b*, over the open top of the glass A,



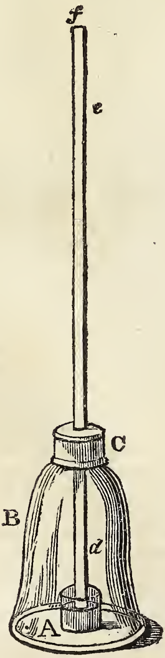
(which is also open at bottom) set it to dry, and then the bladder will be tight like a drum. Then place the open end A upon the pump-plate, over the hole *i*, and begin to exhaust the air out of the glass. As the air is exhausting, its spring within the glass will be weakened, and give way to the pressure of the outward air on the bladder, which, as it is pressed down, will put on a spherical concave figure, which will grow deeper and deeper, until the strength of the bladder be ovorcome by the weight of the air; and then it will break with a report as loud as that of a pistol. If a flat piece of glass be laid upon the open top of this receiver, and joined to it by a flat ring of wet leather between them, upon pumping the air out of the receiver, the pressure of the outward air upon the flat glass will break it all to pieces.

5. Immerse the neck *c d* of the hollow glass ball *e b* in water, contained in the phial *a a*;



then set it upon the pump-plate, and cover it and the hole *i* with the close receiver A: and then begin to pump out the air. As the air goes out of the receiver by its spring, it will also by the same means go out of the hollow ball *e b*, through the neck *c d*, and rise up in bubbles to the surface of the water in the phial; from whence it will make its way with the rest of the air out of the receiver. When the air has done bubbling in the phial, the ball is sufficiently exhausted; and then, upon turning the cock *k*, the air will get into the receiver, and press so upon the surface of the water in the phial, as to force the water up into the ball in a jet, through the neck *c d*; and will fill the ball almost full of water. The reason why the ball is not quite filled, is, because all the air could not be taken out of it, and the small quantity that was left, and had expanded itself so as to fill the whole ball, is now condensed in the same degree as the outward air, and remains like a small bubble at the top of the ball, which keeps the water from filling that part of the ball.

6. Having placed the jar A,



with some quicksilver in it, on the pump-plate, as in the last experiment, cover it with the receiver B; then push the open end of the glass tube *d e*, through the collar of leathers in the brass neck C (which it fits so as to be air tight) almost down to the quicksilver in the jar. Then exhaust the air out of the receiver, and it will come out of the tube, because the tube is close at top. When the gauge *m m* shews that the receiver is well exhausted, push down the tube, so as to immerse its lower end into the quicksilver in the jar. Now, although the tube be exhausted of air, none of the quicksilver will rise into it, because there is no air left in the receiver to press upon its surface in the jar. But let the air into the receiver by the cock *k*, and the quicksilver will immediately rise in the tube, and stand as high in it, as it was pumped up in the last experiment.

These experiments shew, that the quicksilver is supported in the barometer by the pressure of the air on its surface in the box, in which the open end of the tube is placed. And that the more dense and heavy the air is, the higher does the quicksilver rise; and, on the contrary, the thinner and lighter the air is, the more will the quicksilver fall. For if the handle F be turned ever so little, it takes some air out of the receiver, by raising one or other of the pistons in its barrel; and consequently, that which remains in the receiver is so much the rarer, and has so much the less spring and weight; and thereupon the quicksilver falls a little in the tube; but upon turning the cock, and re-admitting the air into the receiver, it becomes as weighty as before, and the quicksilver rises again to the same height. Thus we see the reason why the quicksilver in the barometer falls before rain or snow, and rises before fair weather; for, in the former case, the air is too thin and light to bear up the vapours, and in the latter, too dense and heavy to let them fall.*

7. Take the tube out of the receiver, and put one end of a bit of dry hazel branch, about an inch long, tight into the hole, and the other end tight into a hole quite through the bottom of a small wooden cup: then pour some quicksilver into the cup, and exhaust the receiver of air, and the pressure of the outward air on the surface of the quicksilver, will force it through the pores of the hazel, from whence it will descend in a beautiful shower into a cup placed under the receiver to catch it.

8. Put a wire through the collar of leathers in the top of the receiver, and fix a bit of dry wood on the end of the wire within the receiver; then exhaust the air, and push the wire down, so as to immerse

* In all mercurial experiments with the air-pump, a short pipe must be screwed into the hole *i*, so as to rise about an inch above the plate, to prevent the quicksilver from getting into the air-pipe and barrels, in case any of it should be accidentally spilt over the jar: for if it once gets into the pipes or barrels, it spoils them, by loosening the solder, and corroding the brass.

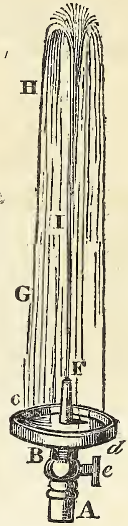
the wood into a jar of quicksilver on the pump-plate; this done, let in the air, and upon taking the wood out of the jar, and splitting it, its pores will be found full of quicksilver, which the force of the air, upon being let into the receiver, drove into the wood.

9. Join the two brass hemispherical cups A and B together,

with a wet leather between them, having a hole in the middle of it; then screw the end D of the pipe C D, into the plate of the pump at *i*, and turn the cock E, so as the pipe may be open all the way into the cavity of the hemispheres; exhaust the air out of them, and turn the cock a quarter round, which will shut the pipe C D, and keep out the air. This done, unscrew the pipe at D from the pump, and screw the piece F *b* upon it at D; and let two men try to pull the hemispheres asunder by the rings *g* and *h*, which they will find difficult to do; for if the diameter of the hemisphere be four inches, they will be pressed together by the external air with a force equal to 188 pounds. And to shew that it is the pressure of the air that keeps them together, hang them by either of the rings upon the hook P of the wire in the receiver M, (upon the air pump) and upon exhausting the air out of the receiver, they will fall asunder of themselves.

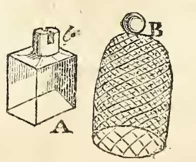
10. Place a small receiver near the hole *i*, on the pump-plate, as O, and cover both it and the hole with the receiver M, (see air pump) and turn the wire so by the top P, that its hook may take hold of the little receiver by a ring at its top, allowing that receiver to stand with its own weight on the plate. Then, upon working the pump, the air will come out of both receivers; but the large one M will be forcibly held down to the pump by the pressure of the external air; whilst the small one O, having no air to press upon it, will continue loose, and may be drawn up and let down at pleasure, by the wire P P. But, upon letting it quite down to the plate, and admitting the air into the receiver M, by the cock *k*, the air will press so strongly upon the small reciever O, as to fix it down to the plate, and at the same time, by counterbalancing the outward pressure on the large receiver M, it will become loose. This experiment evidently shews, that the receivers are held down by pressure, and not by suction, for the internal receiver continued loose whilst the operator was pumping, and the external one was held down; but the former became fast immediately by letting in the air upon it.

11. Screw the end A, of the brass pipe A B F, into the hole of the pump-plate, and turn the cock *e*, until the pipe be open;



then put a wet leather upon the plate *c d*, which is fixed on the pipe, and cover it with the tall receiver G H, which is close at top; then exhaust the air out of the receiver, and turn the cock *e*, to keep it out; which done, unscrew the pipe from the pump, and set the end A into a bason of water, and turn the cock *e* to open the pipe; on which, as there is no air in the receiver, the pressure of the atmosphere on the water in the basin will drive the water forcibly through the pipe, and make it play up in a jet to the top of the receiver.

12. Set the square phial A



upon the pump-plate, and having covered it with the wire cage B, put a close receiver over it, and exhaust the air out of the receiver; in doing of which, the air will also make its way out of the phial through a small hole in its neck under the valve *b*. When the air is exhausted, turn the cock below the plate, to re-admit the air into the receiver: and as it cannot get into the phial again, because of the valve, the phial will be broken into some thousands of pieces by the pressure of the air upon it. Had the phial been of a round form, it would have sustained the pressure like an arch, without breaking; but as its sides are flat, it cannot.

OPTICS.

This defect of the eye (see page 40) is remedied two ways: by diminishing the distance between the object and the eye; for by lessening the distance of the object, the distance of the focus and image will be increased, till it fall on the *retina*, and appear distinct. By applying a concave glass to the eye; for such a glass makes the rays diverge more as they pass to the eye, in which case the distance of the focus will be also enlarged, and thrown upon the *retina*, when distinct vision will ensue.

Hence the use of *concave* spectacles, to *purblind* or near-sighted persons, to whom objects appear under the following peculiarities:

1st. Objects appear nearer than they really are, or do appear to a sound eye.

2d. Objects appear less bright, or more obscure, than to other persons, because a less quantity of the rays of light enter the pupil.

The eyes of such persons grow better with age; for their defect being too great a *convexity* of the eye, the aqueous and crystalline humours waste or decrease with age, and of course grow flatter, and therefore are more capable of viewing distant objects distinctly.

The other defect of the eye arises from a quite contrary cause; namely, the *flatness* of the cornea and crystalline humours. This is generally the case with the eyes of old people; and is remedied by *convex* glasses, such as are used in common spectacles. For as the rays in such eyes go beyond the bottom of the eye, before they come to a focus, or form the image, a convex glass will make the rays converge sooner, by which means the focal distance will be shortened, and adjusted on the retina, where distinct vision will be produced.

By convex spectacles objects appear brighter, because they collect a greater quantity of rays upon the pupil of the eye. They also appear at a greater distance than they are, for the nearer the rays approach to *parallel* ones, the more distant will the point be to which they tend.

A *reading* glass only differs from one of the glasses of a pair of common spectacles in being larger; the use is however somewhat different; for spectacles are used to render objects *distinct* at a given *distance;* but reading glasses are employed to *magnify* objects, or to render the reading of small print very easy, which would otherwise be apt to strain the eye too much. Therefore the size of glasses for spectacles is not required to be larger than the eye itself; but that of a *reading* glass ought to be large enough to take in as much of the object or print, at least, as is equal to the distance between both the eyes.

If an object be placed in the focus of a *convex* lens, or reading glass, the rays which proceed from it, after they have passed through the glass, will proceed parallel; and therefore an eye placed any where in the *axis** of the glass will have the most distinct view of the object possible; and if it be a lens of a small focal distance, the object will appear as much larger than it will do to the naked eye, as it is nearer the lens than to the eye. It is this property which renders them of so much use as single microscopes, of which we shall here give an instance.

Suppose the focal distance of a lens to be $\frac{1}{10}$ of an inch, then will the length of an object, viewed by it, appear 60 times longer than it will do to the naked eye, at six inches distance; the breadth will also be increased 60 times, consequently the area or superficies will appear 3600 times greater than it will appear to the naked eye, when viewed at the distance of six inches.†

As we have now stated and endeavoured to illustrate by figures, the chief properties of convex and concave lenses, we shall give a short account of the nature and theory of the various kinds of *Microscopes.*

There are three sorts of *Microscopes* in use; viz. the *single*, the *double*, and the *solar* microscope.

The nature of the two first depends upon the following circumstances.

1. That no object can be distinctly seen at a less distance, with the naked eye, than six inches.

2. That the nearer any object is, the larger is the angle under which it is seen, or the greater is the magnitude of the object.

3. That *parallel rays*, or such as are nearly

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* See page 13, col. 2.

† This is the least distance at which an object can be distinctly seen with the naked eye, in a sound state.

so, can only have their *focus* at the bottom of the eye.

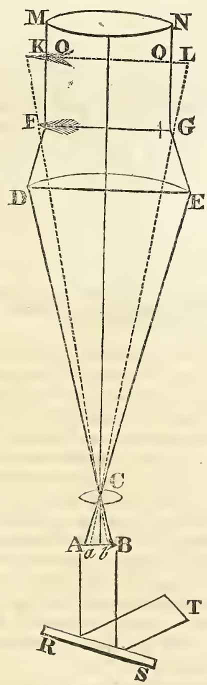
4. That the rays proceeding from an object placed in the focus of a concave lens, are always refracted by the lens into a direction parallel to each other, (see 2d fig. page 37.)

The *Single Microscope,* as has already been stated, consists only of one conevx lens; and when any object is to be examined by it, the object is to be placed in its focus, and the rays which proceed from the object through the lens fall upon the eye parallel to each other, and therefore produce distinct vision.*

The *Double* or *Compound Microscope* consists of two lens at least, but generally of three, and often more.

We shall first describe the one which contains *two;* the lens D E, in the following figure, is therefore to be overlooked in comparing this description with the figure.

The first or smallest lens C is placed near the small object A B,



at a little more than its focal distance from it, a large image of the object is thus formed, which will be as much larger than the object, as the distance C L is greater than the distance A C; and as this distance may be made greater or less, by placing the object nearer to, or farther from, the lens C, the image may be increased or diminished at pleasure. And as this image may be distinctly viewed, and still further magnified, by a convex lens M N, placed at its focal distance from the image, it is evident that small objects may be thus magnified to many times their real size.*

Suppose, for example, that the distance of the object CL is 12 times the distance of the imaget C A, then will the length of the image KL be 12 times the length of the object A B, when viewed with the naked eye; but this length of the image, if viewed with an eye-glass of one inch focal distance, will appear six times as large as it does to the naked eye, and therefore its length will appear 12 times 6, or 72 times larger than to the naked eye; and, as its breadth will be magnified in the same proportion, its *surface* will be 72 times 72, or 5,184 times larger than that of the object when viewed with the naked eye.

Though the magnifying power of this microscope be very considerable, yet the extent or field of view is very small and confined; therefore, in order to enlarge it, and to increase the quantity of light, another large lens D E, is placed between the two already noticed (see the figure), by which means the angle D C E or A C B, under which the visible part of the object appears, may be considerably enlarged; the image will then be formed again at F G, and as the image thus formed is now contained between the two extreme parallel rays of the eye-glass M F and N G, is wholly visible; whereas before, the part O Q could only be seen. But though the object is not quite so much magnified on the whole, in this as in the former case, yet the *visible* surface is very much increased by the addition of this third glass.

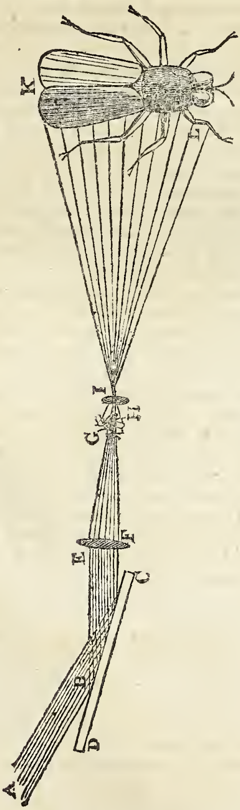
The glass R S is a plain mirror, which is employed to reflect the light I, in order to illuminate transparent objects, when examined by this instrument.

The *Solar Microscope,* invented by Dr. Lieberkhun, is employed to represent very small objects on a very large scale, in a dark room. This is accomplished in the following manner. Let A B (see next page) represent a beam of the sun's light fallling on a small mirror or looking glass D C, adjusted by two brass wheels, to such an inclination as shall reflect the rays which fall upon it parallel to the horizon, to a large convex lens E F, which converges them to a focus; near this focus, as at G H, is placed a small object, which is, by this means, strongly illuminated, and the

* Every convex lens is therefore a single microscope.

* This lens or glass being nearest the eye, is usually called the eye-glass.

rays which flow from it through a small convex lens I, so adjusted by a slider to a little more than its focal distance from the object, produce a very large image K L, which being received upon a white table cloth, or allowed to fall on the opposite wall of the darkened room, will represent the object magnified in proportion to the distance of the picture from the lens I.*

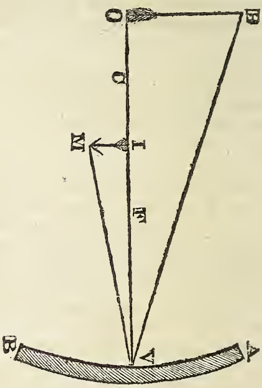


Suppose that the small lens I is $\frac{1}{10}$ of an inch distant from the object, when the image K L is duly formed on a sheet or table cloth, at the distance of 16 feet from the small lens just mentioned: then in 16 feet there are 192 inches, and consequently 1,920 tenths of an inch; therefore the image is 1,920 times the length of the object, and as many times its breadth; the area or surface of the image is therefore 1,920 times 1,920, or 3,086,400 times that of the object. Such is the prodigious magnifying power of the solar microscope.

Having now described the different kinds of microscopes, and endeavoured to explain the principle upon which their construction depends, we shall state the properties of concave and convex *mirrors*, previous to entering upon the description of reflecting and refracting telescopes.

It has already been remarked, at page 12, that when the rays of light fall upon any surface by which they are reflected, that the angle at which they are reflected is equal to the angle at which they fall upon that surface (see fig. 1, in page 12). From this simple elementary principle may easily be inferred every thing relating to the formation of the images of objects in a concave mirror.

For let A B be such a mirror,



and O B an object placed beyond its centre C, then since the axis C V is perpendicular thereto in the vertex V, the particle of light coming from the point O of the object in the direction of the axis, will be reflected back in the same direction to its focus at I, where the point at O will be represented. Then from the other extreme point B let a ray proceed to V, making the angle I V M equal to B V O, and the point M will be the representation of the point B. And hence all the rays proceeding from every part between O and B will be reflected to the line I M, and so the whole line I M will be the representation or image of the object O B.

Hence it appears that the *position of the image*, with respect to that of the object, must necessarily be *inverted*, and on the contrary side of the axis. Hence also it appears, since the object and the image are both seen from the vertex of the mirror under equal angles B V O and I V M, the length of the object will be to that of the

* It is scarcely necessary to remark that, the lenses and object to be viewed are placed in a tube, which is screwed into a hole in the window shutter, or a board placed in the window, which serves at the same time to exclude the light.

image as the distance O V, to the distance of the image I V from the mirror.

Therefore, while the object is farther from the glass than the centre C, the image will be on the same side, but nearer to it, and less than the object. If the object were placed in the centre C, the image would be there formed also, in an inverted position, and equal to the object; if the object be placed between the centre C and focus F, as at I M, then will O B be the image formed beyond the centre, *inverted* and *magnified*.

If the object be placed in the focus F, the rays will be all reflected parallel to the axis, and form the image, and at an infinite distance, and infinitely large. Lastly, suppose the object placed any where between the focus F, and the vertex V, as at K, the image will be formed behind the glass at M, in the same position as the object, and magnified.

If the radius of the mirror's concavity and the distance of the object be known, the distance of the image from the mirror may be found as follows: divide the product of the distance and radius by double the distance diminished by the radius, and the quotient is the distance required.

Thus, let the radius of the mirror's concavity be 8 inches, and the distance of the object 5 inches, required the distance of the image from the mirror? Here the product of 8 and 5 is 40, and double the distance of the object from the mirror is 10, which diminished by 8, the radius, leaves 2; and 40 divided by 2 quotes 20, which is the number of inches that the image is distant from the mirror, in this case.

If a man places himself directly before a large concave mirror, but farther from it than its centre of concavity, he will see an inverted image of himself in the air, between him and the mirror, of a less size than himself. And if he holds out his hand towards the mirror, the hand of the image will come out towards his hand, and coincide with it, of an equal bulk, when his hand is in the centre of the concavity: and he will imagine he may shake hands with his image. If he reaches his hand farther, the hand of the image will pass by his hand, and come between his hand and his body; and if he moves his hand towards either side, the hand of the image will move towards the other; so that whatever way the object moves, the image will move the contrary.

All the while a by-stander will see nothing of the image, because none of the reflected rays that form it enter his eyes.

If a fire be made in a large room, and a smooth mahogany table be placed at a good distance near the wall, before a large concave mirror, so placed, that the light of the fire may be reflected from the mirror to its focus upon the table; if a person stand by the table, he will see nothing upon it, but a longish beam of light; but if he stands at a distance towards the fire, not directly between the fire and the mirror, he will see an image of the fire upon the table, large and erect. And if another person, who knows nothing of this matter before hand, should chance to come into the room, and should look from the fire towards the table, he would be startled at the appearance; for the table would seem to be on fire, and by being near the wainscot, to endanger the whole house. In this experiment there should be no light in the room but what proceeds from the fire; and the mirror ought to be at least fifteen inches in diameter.

If the fire be darkened by a screen, and a large candle be placed at the back of the screen, a person standing by the candle will see the appearance of a fine large star, or rather planet, upon the table, as bright as Venus or Jupiter. And if a small wax taper (with a flame much less than the flame of a candle) be placed near the candle, a *satellite* to the planet will appear on the table; and if the taper be moved round the candle, the satellite will go round the planet.

In the same manner it may be shown, that the rays of light falling on a convex mirror, will proceed diverging from the glass in such a manner as if they came from a point behind it, so that these glasses have no real focus or burning point; they form the image *only behind*, *always erect*, and *less than the object;* so that no magnifying power belongs to these glasses, when used alone.

CHEMISTRY.

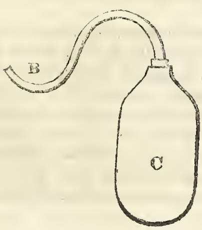
OF HYDROGEN GAS.

Another substance presents itself in the same state as oxygen; for chemists have never been able to procure it in a pure and separate state, and they have yet no proof that it exists in that state in nature. In order to discover its properties, they are obliged to examine the bodies which contain it, and by this means they are, in some measure, enabled to discover the properties it communicates to those bodies.

Though we have long possessed some knowledge of the natural inflammable vapours of the mines, and coal pits, as well as of those which are disengaged in many operations of chemistry, such as the metallic solutions in the acids, &c.; it was not till 1766 that M. Cavendish ascertained the existence of this elastic fluid, and properly distinguished it from all others, by collecting it separately, and distinguishing its properties.

Hydrogen gas is not to be collected from natural bodies. That which is abundantly disengaged from fossil coal, moistened or exposed to the air, of putrid vegetables at the bottom of stagnant waters, of ponds, of marshes, of peat soil, contains but a small quantity of pure hydrogen gas. It contains many different substances in solution, and its properties vary singularly according to the number and the proportion of these substances. It is the same with what exhales from flaming volcanos, red lava flowing into water, and from sulphureous mineral waters. It will be shown hereafter, that these gases are rather different species of inflammable gases, of which hydrogen gas indeed constitutes the base, but in which this gas is the solvent of many different matters, and in various proportions.

Hydrogen gas is the lightest species of ponderable matter yet known. It can be procured only from water, of which it forms an essential constituent. The method of procuring it is as follows. Into a phial or gas bottle C,



furnished with a bent tube B, which is ground to fit the mouth of the phial; put some pieces of pure re-distilled zinc, or harpsichord iron wire, and pour on them sulphuric acid, diluted with five times its bulk of water. An effervescence will ensue, occasioned by the decomposition of the water, and disengagement of hydrogen, which may be collected in the pneumatic apparatus. For very accurate researches, it must be received in jars over mercury, and exposed to the joint action of dry muriate of lime, and a low temperature. It is thus freed from hygrometric water. In this state its specific gravity is 0·0694, at 60° F. and 30 inches of barom. pressure. 100 cubic inches weigh 2,118 grains. It is therefore about 14·4 times less dense than common air; 16 times less dense than oxygen: and 14 times less dense than azote. When it stands over water at 60°, its sp. gr. acquires an increase of nearly one-seventh; and it becomes about 0·0790. From the great rarity of hydrogen gas, it is employed for the purpose of inflating varnished silk bags, which are raised in the air, under the name of balloons.

This gas is colourless, and posssssed of all the physical properties of air. It has usually a slight garlic odour, arising propably from arsenical particles derived from the zinc. When water is transmitted over pure iron in a state of ignition, it yields hydrogen gas free from smell. It is eminently combustible, and, if pure, burns with a yellowish-white flame; but from accidental contamination, its flame has frequently a reddish tinge. If a narrow jar, filled with hydrogen, be lifted perpendicularly, with the bottom upwards, and a lighted taper be suddenly introduced, the taper will be extinguished, but the gas will burn at the surface, in contact with the air. Animal life is likewise speedily extinguished by the respiration of this gas, though Sir H. Davy has shewn, that if the lungs be not previously exhausted by a forced respiration, it may be breathed for a few seconds without much seeming inconvenience.

When five measures of atmospheric air are mixed with two of hydrogen, and a lighted taper, or an electric spark, applied to the mixture, explosion takes place, three measures of gas disappear, and moisture is deposited on the inside of the glass. When two measures of hydrogen, mixed with one of oxygen, are detonated, the whole is condensed into water. Thus, therefore, we see the origin of the name *hydrogen*, a term derived from the Greek, to denote the *water-former*. If a bottle, containing the effervescing mixture of iron and dilute sulphuric acid, be shut with a cork, having a straight tube of narrow bore fixed upright in it, then the hydrogen will issue in a jet, which, being kindled, forms the philosophical candle of Dr. Priestley. If a long glass tube be held over the flame, moisture will speedily bedew its sides, and harmonic tones will then begin to be heard. Mr. Faraday, in an ingenious paper inserted in the 10th Number of the Journal of Science, states, that carbonic oxide produces, by the action of its flame, similar sounds, and that therefore the effect is not due to the affections of aqueous vapour, as had formerly been supposed. He shews, that the sound is nothing more than the report of a continued explosion, agreeably to Sir H. Davy's just theory of the constitution of flame. Vapour of ether, made to burn from a small aperture, produces the same sonorous effect as the jet of hydrogen, of coal gas, or olefiant gas, on glass and other tubes. Globes from seven to two inches in diameter, with short necks, give very low tones; bottles, Florence flasks, and phials, always succeeded; air jars, from four inches diameter to a very small size, may be used. Some irregular tubes were constructed of long narrow slips of glass and wood, placing three or four together, so as to form a triangular or square tube, tying them round with pack-thread. These held over the hydrogen jet, gave distinct tones.

Hydrogen, combined with oxygen, forms water—

With Chlorine .	muriatic acid,
Iodine . .	hydriodic acid,
Prussine .	prussic acid,
Carbon . .	sub-carb. and carb. hydr.
Azote . .	ammonia,
Phosphorus	subphos, & subsul. hydr.
Sulphur .	sulph. and subsul. hydr.
Arsenic .	arsenuretted hydrogen,
Tellurium	telluretted hydrogen,
Potassium	potassuretted hydrogen.

In the Philosophical Magazine, we have the following notice of the effect of hydrogen gas on the voice: "The *Journal Britannique*, published at Geneva by Prevost, contains the following article: 'Maunoir was one day amusing himself with Paul at Geneva, in breathing pure hydrogen gas. He inspired it with ease, and did not perceive that it had any sensible effect on him, either in entering or passing out of his lungs. But after he had taken in a very large dose, he was desirous of speaking, and was astonishingly surprised at the sound of his voice, which was become soft, shrill, and even squeaking, so as to alarm him. Paul made the same experiment on himself, and the same effect was produced. I do not know whether any thing similar has occurred in breathing any of the other gases.'"

OF CARBON.

The name of Carbon has been given by the French chemists, to a simple or undecomposed matter, abundantly contained in the different known species of coal, but which it is very essential should not be confounded with what is properly called charcoal. This last substance is most frequently a black matter, which remains after the partial decompositions of vegetable or animal substances, effected by nature or by art. Besides the carbon which it conceals in its composition, it is loaded with many other substances which are foreign to carbon, and cannot completely be separated but by perfect combustion.

It is, therefore, necessary, in order to form a proper notion of the nature of carbon, to adopt ideas similar to those which were detailed in the preceding articles concerning oxygen and hydrogen. Pure carbon does not exist in nature, nor has it yet been produced by art, any more than the bodies just mentioned; or at least, if carbon exists pure, or insulated, in any part of the globe, chemists have not yet discovered it. But, notwithstanding this resemblance, carbon differs materially from oxygen and hydrogen; namely, in this circumstance, that it is never found united to caloric under the gaseous form, and also that, even in the state of charcoal, it may, at least, in some species of the charcoals, be regarded as nearer to its state of purity, and more proper to exhibit the properties which characterise it, than these two bodies in any of their combinations.

Carbon also differs essentially from oxygen, for it is no where collected in such great masses, though it is very abundant among natural combinations. It is, undoubtedly one of the principles which nature abundantly employs in the formation of compounds; but it is never found combined in a mass like oxygen gas. It appears, however, that though far from a state of purity, it exists, at least, under the fossil form in depositions, or beds, and veins, in the interior of the globe.

Carbon is procured, not, however, pure and separated from every other body, but more or less approaching to purity, by decomposing most vegetable substances, by heat, especially ligneous, or woody bodies, which contain a great quantity of it. From these it is obtained in the state of charcoal. The carbon is united with some foreign bodies, and a little oxygen and hydrogen, the volatilizing of all the evaporable substances united with it in wood, constitutes the art of the charcoal burner. The water, in which trees are suffered to remain, produces the same effect, but more slowly, upon the ligneous vegetable body. It gradually dissolves the different soluble materials of that body, and leaves its charcoal free.

If a piece of wood be put into a crucible, well covered with sand, and kept red hot for some time, it is converted into a black shining brittle substance, without either taste or smell, well known under the name of *charcoal*. Its properties are nearly the same from whatever wood it has been obtained, provided it be exposed for an hour in a covered crucible to the heat of a forge.

Charcoal is insoluble in water. It is not affected (provided that all air and moisture be excluded) by the most violent heat which can be applied, excepting only that it is rendered much harder and more brilliant.

It is an excellent conductor of electricity, and possesses besides a number of singular properties, which render it of considerable importance. It is much less liable to putrefy or rot than wood, and is not therefore so apt to decay by age. This property has been long known. It was customary among the ancients to *char* the outside of those stakes which were to be driven into the ground or placed in water, in order to preserve the wood from spoiling. New-made charcoal, by being rolled up in cloths which have contracted a disagreeable odour, effectually destroys it. When boiled with meat beginning to putrefy, it takes away the bad taint. It is perhaps the best teeth powder known. Mr. Lowitz of Petersburgh has shewn, that it may be used with advantage to purify a great variety of substances.

New-made charcoal absorbs moisture with avidity; when heated to a certain temperature, it absorbs air copiously. La Metherie plunged a piece of burning charcoal into mercury, in order to extinguish it, and introduced it immediately after into a glass vessel filled with common air. The charcoal absorbed four times its bulk of air. On plunging the charcoal into water, one-fifth of this air was disengaged. This air, on being examined, was found to contain a much smaller quantity of oxygen than atmospherical air does. He extinguished another piece of charcoal in the same manner, and then introduced it into a vessel filled with oxygen gas. The quantity of oxygen gas absorbed amounted to eight times the bulk of the charcoal; a fourth part of it was disengaged on plunging the charcoal into water.

This property of absorbing air, which new-made charcoal possesses, was observed by Fontana, Priestley, Scheele, and Morveau; but Morozzo was the first philosopher who published an accurate set of experiments on the subject.

These experiments have been lately repeated upon a larger scale by Mr. Rouppe, professor of chemistry at Rotterdam, and Dr. Van Noorden of the same city. They filled a copper box, which was made air-tight, with red-hot charcoal, allowed it to cool under water, and then introduced it into a glass jar full of air. Seventeen cubic inches of charcoal absorbed, in five hours, 48 cubic inches of air, or $\frac{1}{3}$ nearly of its bulk. This absorption, though much more considerable than could have been expected from former experiments, has since been confirmed by several chemists.

When charcoal is heated to about 802°, or when it is made nearly red hot, and then plunged into oxygen gas, it takes fire; and, provided it has been previously freed from the earths and salts which it generally contains, or if we employ *lamp black*, which is charcoal nearly pure, it burns without leaving any residuum. But the air in which the combustion has been carried on has altered its properties very considerably, for it has become so noxious to animals that they cannot breathe it without death If small pieces of dry charcoal be placed upon a pedestal, in a glass jar filled with oxygen gas, and standing over mercury, they may be kindled by means of a burning glass, and consumed. The bulk of the gas is not sensibly altered by this combustion, but its properties are greatly changed. A great part of it will be found converted into a new gas quite different from oxygen. This new gas is easily detected by letting up *lime-water* into the jar; the lime-water becomes milky, and absorbs and condenses all the new-formed gas. This new gas has received the name of *carbonic acid*. Mr. Lavoisier ascertained, by a very laborious set of experiments, that it is precisely equal in weight to the charcoal and oxygen gas.

Carbon, when pure and free from the foreign substances with which it is united in charcoals, appears to exist under the form of solid particles, of a black so determinate, as would lead us to think that it is essentially of that colour, and that it communicates it to a number of other bodies. It is the excess of carbon, as will be noticed hereafter, which produces the greater part of vegetable colours, and which also renders them durable and intense. It appears also that it gives the same shade in some mineral compounds, of which it forms an essential part.

But there are, nevertheless, reasons for thinking that the black colour of charcoals is not a true character of *carbon*, and that it accompanies its union with a small portion of oxygen and hydrogen, from which, in its state of charcoal, it is never exempt.

The diamond which, under certain relations, nearly approaches to pure carbon, is so much the more white and transparent as it is less altered by foreign substances.

Carbon has neither taste nor smell, and its particles never possess an adherence sufficiently strong to prevent their being very brittle; this brittleness is also greater in charcoals as the carbon is more contaminated with other bodies. It is probable that the particles of carbon always remain at a very great distance from each other. They do not possess the property of disposing themselves regularly, and never permit it to assume a crystaline form in the state of charcoal, although it is highly probable that it is capable of this arrangement when very pure.

ASTRONOMY.

THE SOLAR SYSTEM.

The Solar, or true system of the world, as already observed, was taught by Pythagoras; but aftewards lost till the time of Copernicus, who again revived it, and from this circumstance it is often called the Copernican System.*

In this system, the Sun is placed nearly in the centre of the orbits of all the planets

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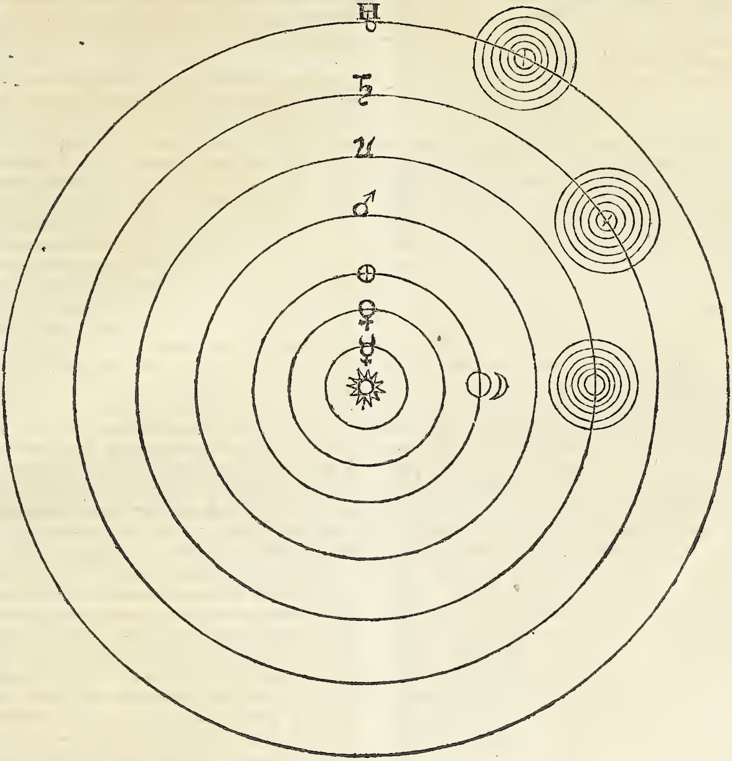
* From the labours of Sir Isaac Newton to establish the system of Copernicus, it is sometimes called the *Newtonian* system.

and comets; and in these orbits they perform their revolutions round the Sun in their respective periodic times. The number of planets at present known to belong to the solar system is 29, of which 11 are Primary, and 18 Secondary.

The Primary planets are those that circulate round the Sun as their centre, viz. Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus or Georgium Sidus, Ceres, Pallas, Juno, and Vesta. See the following Figure.*



The first six were known to the ancients, and are therefore called the *old* planets. The five last have been discovered since the year 1781, and are often called the *new* planets.

Those planets that have their orbits included within the Earth's orbit, are called *Inferior*, and those without the orbit of the Earth, are called *Superior* planets.

The Moon is a secondary belonging to the Earth, and circulates round it while the Earth continues its annual course round the Sun. Jupiter has four secondaries or satellites revolving round him; Saturn has seven; and Uranus has six.

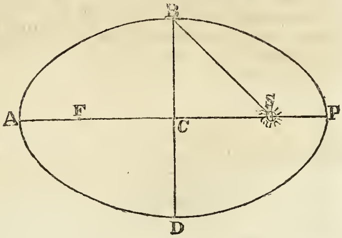
The orbits or paths in which the Primary Planets perform their revolutions round the Sun, and the Secondaries round their Primaries, are not exactly circles, but Ellipses or Ovals.†

Now, though this be the form of the orbit which the planet describes, yet the place

* This figure represents the order in which these planets move round the sun; but the circles which represent the respective orbits, do not show the proportioned distance of each planet from the sun. To do this accurately would require a very large figure. By mistake Saturn is here represented to have only six satellites instead of seven.

† If the two ends of a thread be tied together and thrown loosely over two pins stuck in a table, as S and F, fig. next page, and if the thread be moderately stretched by the point of a pen or black lead pencil, and carried round the pins by an even motion and slight pressure of the hand, an ellipse or oval will be described; the points A and P, where the pins were fixed, are called the foci or focuses of the ellipse. The figure described will be the more elliptical the tighter the thread is to the pins in the foci.

of the Sun is not in the centre of the orbit, but in one of the Foci, as at S.



When the planet is at P, it is then nearest the Sun, and is said to be in its Perihelion. In moving from P, its distance from the Sun gradually increases till it reaches the opposite point A, when it is at its greatest distance from the Sun, and is then said to be in its Aphelion. When it arrives at the points B and D, it is said to be at its Mean Distance. The straight line A P, which joins the perihelion and aphelion, is called the line of the Apsides, and sometimes the greater axis or the transverse axis of the orbit. The line B D, joining the points of *mean* distance, is called the Conjugate or lesser axis: SB or SD, the planet's mean distance from the Sun; SC or FC, the Eccentricity of the orbit, or the distance of the Sun from its centre; S the lower Focus, or that in which the Sun is placed; F the higher Focus; P the *lower Apsis*, and A the *higher Apsis*. Though the Primary Planets have all nearly the same common focus in which the Sun is situated, yet they have not all the same degree of ellipticity. Most of them deviate but little from the circular form, and none of them so much as the last figure. The orbits of the different planets do not all lie in the same plane, as they appear to do when represented on paper.

If the Earth's orbit be supposed to be a thin solid plane, and to be extended in every direction, it will mark out a line in the starry heavens, which is called the *Ecliptic*, and the plane itself is called the *Plane of the Ecliptic*. The orbits of all the other planets lie in planes different from this plane; but the one half of each orbit rises above it, and the other falls below it,* consequently the orbit of each planet crosses the ecliptic in two opposite points, which are called the planet's *Nodes*. These nodes are all in different parts of the Ecliptic, and therefore if the planetary tracks remained visible in the heavens, they would in some measure resemble the different ruts of waggon wheels crossing each other in various parts, but never going far asunder. That *node* or intersection where the orbit ascends above the ecliptic, is called the *ascending node*, and the other, which is directly opposite to it, is called the *descending node*

While the primary planets are performing their revolutions round the Sun, and the secondaries round their primary planets, they have all a motion from west to east round an imaginary line passing through their centres, called their axes. The axis of some of the planets is much more inclined to the axis of its orbit than others, and on this depends the change of seasons in the planet; * for the more the axis of any planet is inclined to the axis of its orbit, the greater will be the variety of its seasons.† The extremities of the axis of any planet are called its Poles. That which points towards the northern part of the heavens is called the North Pole, and the other pointing towards the southern part is called the South Pole.

As the Earth turns round its axis in 24 hours, the heavens will appear to make a complete revolution in that time: and to a spectator on any of the other planets, this revolution will seem to be performed in the time which this planet takes to perform a revolution on its axis, which is called the length of the planet's day.

As it is necessary to have some method by which the position of any celestial body may be determined at any time, or its distance from some known point, astronomers have fixed on the Ecliptic or Earth's orbit for this purpose, as well as for reckoning from it the inclination of the planetary orbits. The line of the Equinoxes, or that line in which the Earth's equator, when extended to the heavens, cuts the Ecliptic (being always in the plane of the Ecliptic) must mark out two points of that line traced among the stars; and from one of these points astronomers reckon the distances on the ecliptic. This point is called the *vernal* Equinox, because the Sun appears in it about the middle of Spring or the 20th of March; its opposite is called the *autumnal* Equinox, the Sun being in it about the middle of Autumn, or the 23d of September.

The Ecliptic is supposed to be divided into twelve equal parts, called signs, of 30

* The angle which each orbit makes with the plane of the ecliptic, is called the inclination of the orbit. The orbit of Mercury is inclined 7° to the plane of the ecliptic; Venus $3^\circ\ 23'$; Mars $1^\circ\ 51''$; Jupiter $1^\circ\ 19''$; Saturn $2^\circ\ 30'$: Uranus $0^\circ\ 46\frac{1}{3}'$; Ceres $10^\circ\ 37'$; Pallas $34^\circ\ 50'$; Juno 21°; and Vesta $7^\circ\ 9'$. The orbits of all the *old* planets are included in the zodiac, which is a belt or zone in the heavens, extending about 8° on each side of the ecliptic: but the orbits of the new planets are without the zodiac.

* The axis of the Earth is inclined $23^\circ\ 28'$ to the axis of its orbit, which is the cause of the different lengths of the days, and variety of the seasons.

† The axis of the orbit of any planet is a straight line perpendicular or at right angles to the orbit.

degrees each. Their names and characters are the following.

Aries	♈	Libra	♎
Taurus . . .	♉	Scorpio	♏
Gemini . . .	♊	Saggittarius . .	♐
Cancer	♋	Capricornus. .	♑
Leo	♌	Aquarius . . .	♒
Virgo	♍	Pisces . - . . .	♓

The *Longitude* of all the heavenly bodies is reckoned eastward on the ecliptic from the vernal equinox (where the sign Aries begins) quite round the heavens.

The *Latitude* of any celestial body is reckoned from the ecliptic, north and south; but its Declination is counted from the Equinoctial, in a similar manner.

The *Right Ascension* of any celestial body is reckoned on the *equinoctial* from the vernal equinox, or the first point of Aries, eastward quite round the heavens.

Instead of the Vernal Equinox, astronomers sometimes find it convenient to count the distance of a planet from its Aphelion. This distance is called the true Anomaly of the planet.

OF THE SUN.

The Sun is the largest body yet known in the universe. His diameter is 887,693 English miles; his circumference 2,800,000, and his bulk is above 1,400,000 times greater than the Earth. Although the Sun be the fixed centre of the universe, he has been discovered to have a motion round his axis in 25 days 10 hours, and another round the centre of gravity of the planetary motions. The motion round his axis was discovered by Galileo in the year 1611.

When the Sun is examined with a telescope of a tolerable magnifying power, and a piece of dark glass interposed to prevent his rays from hurting the eye, a number of dark Spots, of various forms and magnitudes, are frequently perceived on his disc. These spots are sometimes so very large as to be perceptible with the naked eye. The nature and formation of the Solar Spots have been the subject of much speculation and conjecture. Some astronomers have affirmed that the Sun is an opaque body, mountainous and uneven like the Earth, and covered all over with a fiery and luminous fluid: that this fluid ebbs and flows after the manner of our tides, so as sometimes to leave uncoveied the tops of rocks or hills, which appear like black Spots, and that the nebulosities about them are caused by a kind of froth. Others have imagined, that the fluid which sends us so much light and heat contains a nucleus or solid globe, wherein are several volcanoes, which, like Ætna or Vesuvius, from time to time, cast up quantities of bituminous matter to the surface of the Sun, and form those Spots that are perceptible on his disc; and that this matter is gradually consumed by the luminous fluid, and then the Spots disappear for a time, but are seen to rise again in the same places when those volcanoes cast up new matter. A third opinion is, that the Sun consists of a fiery luminous fluid, wherein are immersed several opaque bodies of irregular shapes; and that these bodies, by the rapid motion of the Sun, are sometimes buoyed or raised up to the surface, where they form the appearance of Spots, which seem to change their shapes according as different sides of them are exposed to our view. A fourth opinion is, that the Sun consists of a fluid in continual agitation; that, by the rapid motion of this fluid, some parts more gross than the rest, are carried up to the surface of the luminary, like the scum of melted metal rising up to the top in a furnace; and that these scums, as they are differently agitated by the motion of the fluid, form themselves into those Spots that are visible on the solar disc.

Dr. Herschel supposes the Sun an opaque body like the planets, surrounded by an atmosphere of a phosphoric nature, with a number of luminous clouds floating on it; and that the dark nucleus of the Spots are occasioned by the opaque body of the Sun appearing through openings in his Atmosphere.

The late Dr. Wilson of Glasgow has advanced a new opinion respecting the solar Spots. He supposes, with great appearance of truth, that they are depressions rather than elevations; and that the dark nucleus of every Spot is the opaque body of the Sun seen through an opening in the luminous Atmosphere with which he is surrounded.

Amidst all these conjectures, we are still left in uncertainty: for there appears little in any of them to entitle it to a superioritl over the other. In one particular they aly agree; namely, that the Sun is either composed of, or surrounded by, some very powerful heating substance; but what that substance is, or how it is maintained, they are all at a loss to determine. Many experiments have been made, both in this country and on the continent, to determine the Heat of the Sun, or the *intensity* of his rays, when concentrated in the focus of a lens, or by reflecting mirrors. Among these may be mentioned the experiments made by Dr. Harris and Dr. Desaguliers, with a mirror constructed by Mr. Vilette. It was 3 feet 11 inches in diameter, and its focal distance was 3 feet 2 inches. A fossil shell was calcined by it in 7 seconds, copper ore vitrified in 8 seconds; iron ore melted in 24 seconds: talc began to calcine in 40 seconds; a great fish's tooth melted in $32\frac{1}{2}$ seconds; a silver sixpence melted in $7\frac{1}{2}$ seconds; a copper halfpenny melted in 20 seconds; tin melted in 3 seconds; cast iron in 16 seconds; slate melted in 3 seconds; bone was calcined in 4 seconds. So powerful are the Sun's rays when condensed by burning glasses, that it is said Archimedes set fire to the Roman fleet at the siege of Syracuse by a combination of these glasses; and Buffon, in the year 1747, constructed a reflecting mirror of 168 plane glasses, moveable on hinges, with which he set wood on fire at the distance of 150 feet, and melted lead at 145 feet.

To be continued.

Miscellaneous Subjects.

SOLUTIONS OF QUESTIONS, In No. III.

To the Editor of the Artisan.

Sir,—In the third number of your excellent publication, there is a question, by Andrew Asker, requiring the height to which a balloon, containing 10,000 cubical feet, and loaded with 350 pounds, will ascend: I have solved the question, and enclosed the solution, which if you think proper to insert in your next number, will oblige, sir, &c. &c. Lunardi.

Let y be the specific gravity of the *stratum* of air in which the balloon floats, when at its greatest height *(water being unity)*; then, since a cubic foot of water weighs 62·48 lbs. avoirdupois, at the temperature of 60°, the weight of the air displaced, or force tending to support the balloon, is $62{\cdot}48 \times 10000 \times y$, or $624800\,y$. But the whole weight of the balloon is $350 + (62{\cdot}48 \times 10{,}000) \times \frac{y}{13}$, and therefore, when the balloon is just supported, and has no tendency to ascend, $624800\,y = 350 + (62{\cdot}48 \times 10{,}000) \times \frac{y}{13}$, consequently $y = \frac{455}{874720}$, or ·00052017, the density of the air at the greatest height the balloon will reach. And assuming the density or elasticity of the air at the surface of the earth to be ·0015224 (as it has been found to be when the barometer stands at 30 inches) the height is determined by the rules for barometric measurement; and in the present case I shall apply the rule given at page 33 of the "Artisan," as it is less complex than any other.

The height of the mercury in the barometer being directly proportional to the density of the air, the height of the mercury at the balloon is determined, (supposing it 30 inches at the surface) thus 105224 : 52017 : : 30 : 14·83,

Then 30
 14.83

$\overline{44{\cdot}83}$: 15·17 : : 52·000 : 17.596·3 feet, which is only the approximate height according to the rule; but the correction to be applied on account of the expansion of the air is not necessary in the present example, as the question states that the air is to be considered "under the same compression."

I have, however, computed the correction, by first determining the temperature of the balloon, when highest, by the formula at page 33, 1st col. of the "Artisan," and found it to be 1801·6 feet; therefore the whole height is $17596{\cdot}3 + 1807{\cdot}6 = 19397{\cdot}9$ feet.

TRIGONOMETRICAL SURVEY OF GREAT BRITAIN.

It appears from a memoir lately read before the Royal Society, that the result of the Trigonometrical Survey of Altitudes in Great Britain, relatively to the different sections of the meridian, has not yet been verified in a manner so satisfactory as could be wished.

In order to rectify the anomalies which some of the calculations present, and particularly in the one which respects Arbury Hill, Northamptonshire, Sir B. Bevan (the author of the memoir) has determined the altitude of that station, by the process of leveling with the greatest care, to the Grand Junction Canal. From this he deduced the altitudes of the greater part of the important points in the counties of Northampton, Buckingham, and Bedford; the *latitude*, by these calculations, is found 5″ less than that given by the zenith sector, which renders it highly probable that the difference is produced by the local attraction of the mountains to the south of that station.

The altitude of the Grand Junction Canal near Tring, is, according to him, 402 feet above the level of the sea at low spring tides, which gives $740\frac{1}{2}$ for the altitude of Arbury Hill, in place of 804, as stated in the Survey. Sir B. has also rectified the altitudes of various other stations, which he found not perfectly correct. But it ought to be remembered, that in operations of this kind, the accuracy of the results depends much upon the goodness of the instruments employed in the operation.

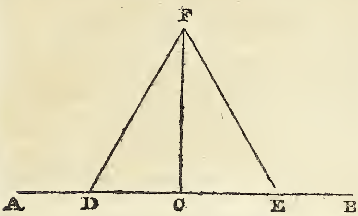
GEOMETRY.

PROPOSITION XI.

Problem.—*To draw a straight line at right angles or perpendicular to a given straight line, from a given point in the same.*

Let A B be a given straight line, and C a point given in it: it is required to draw a straight line from the point C at right angles to A B.

Take any point D in A C, and make C E



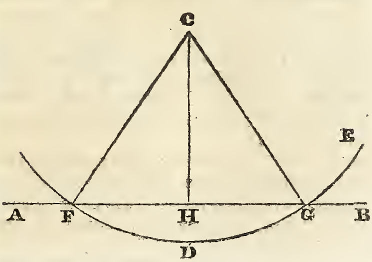
equal to C D, and upon D E describe the equilateral triangle D F E, and join F C; the straight line F C drawn from the given point C, is at right angles to the given straight line A B.

Because D C is equal to C E, and F C common to the two triangles D C F, E C F, the two sides D C, C F, are equal to the two EC, CF, each to each; but the base DF is also equal to the base E F; therefore the angle D C F is equal to the angle ECF; and they are adjacent angles. But when the adjacent angles which one straight line makes with another straight line are equal to one another, each of them is called a right angle; therefore each of the angles D C F, E C F, is a right angle. Wherefore, from the given point C, in the given straight line A B, F C has been drawn at right angles to A B. Which was to be done.

PROPOSITION XII.

Problem.—*To draw a straight line at right angles (or perpendicular) to a given straight line of an unlimited length from a given point without it.*

Let A B be a given straight line, which may be produced to any length both ways,



and let C be a point without it. It is required to draw a straight line perpendicular to A B from the point C.

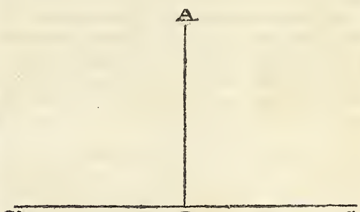
Take any point D upon the other side of A B, and from the centre C, at the distance C D, describe the circle E G F meeting AB in F G: and bisect F G in H, and join CF, C H, C G; the straight line C H, drawn from the point C, is perpendicular to the given atraight line A B.

Because F H is equal to H G, and H C common to the two triangles F H C, G H C, the two sides F H, H C are equal to the two G H, H C, each to each; now the base CF is also equal to the base C G; therefore the angle C H F is equal to the angle C H G: and they are adjacent angles; but when a straight line standing on a straight line makes the adjacent angles equal to one another, each of them is a right angle, and the straight line which stands upon the other is called a perpendicular to it; therefore from the given point C a perpendicular C H has been drawn to the given straight line A B. Which was to be done.

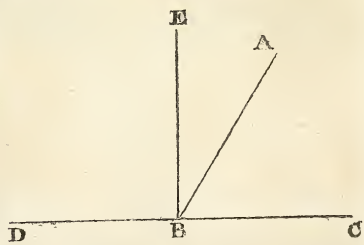
PROPOSITION XIII.

Theorem.— *The angles which one straight line makes with another upon the one side of it, are either two right angles, or are together equal to two right angles.*

Let the straight line A B make with CD, upon one side of it, the angles CBA, ABD; these are either two right angles, or are together equal to two right angles.



For if the angle C B A be equal to A B D, each of them is a right angle; but, if not,



from the point B draw B E at right angles to C D: therefore the angles C B E, E B D are two right angles. Now, the angle C B E is equal to the two angles C B A, A B E together; add the angle E B D to each of these equals, and the two angles C B E, E B D will be equal to the three C B A, A B E, E B D. Again, the angle D B A is equal to the two angles D B E, E B A; add to each of these equals the angle A B C; then will the two angles D B A, A B C be equal to the three angles D B E, E B A, A B C: but the angles C B E, E B D have been demonstrated to be equal to the same three angles; and things that are equal to the same are equal to one another: therefore the angles CBE, E B D are equal to the angles DBA, ABC; but C B E, E B D are two right angles; therefore D B A, A B C are together equal to two right angles. Wherefore, when a straight line, &c. Q E D.

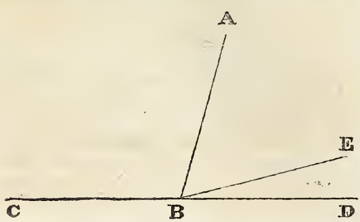
Learners are generally perplexed with demonstrations of which they cannot previously understand something of the plan and scope, and with none more frequently than that of this proposition. Let such as find it difficult, observe, *first*, that C B E, E B D are, *by construction*, two right angles; *secondly*, that the three angles C B A, A B E, E B D, are equal to the above two, consequently to two right angles; and, *thirdly*, that the two given angles D B A, A B C are equal to the last-mentioned three, consequently to the fore-mentioned two, and therefore to two right angles; which was proposed to be proved.

Corollary.—Hence, if the angles A B D, A B C be unequal, the greater is obtuse, and the less acute; the former being as much greater than a right angle, as the latter is less, as is evident from the proposition.

PROPOSITION XIV.

Theorem.—*If, at a point in a straight line, two other straight lines, upon the opposite sides of it, make the adjacent angles together equal to two right angles, these two straight lines shall be in one and the same straight line.*

At the point B in the straight line A B, let the two straight lines B C, B D upon the opposite sides of AB, make the adjacent angles A B C, A B D equal together to two right angles. B D is in the same straight line with C B.



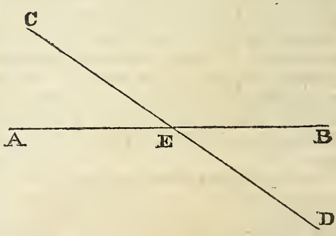
For if B D be not in the same straight line with C B, let B E be in the same straight line with it; therefore, because the straight line A B makes angles with the straight line C B E, upon one side of it, the angles A B C, A B E are together equal to two right angles; but the angles A B C, A B D are likewise together equal to two right angles; therefore the angles D B A, A B E are equal to the angles C B A, A B D: Take away the common angle A B C, and the remaining angle A B E is equal to the remaining angle A B D, the less to the greater, which is impossible; therefore BE is not in the same staight line with B C. And in like manner, it may be demonstrated, that no other can be in the same straight line with it but C D, which therefore is in the same straight line with C B. Wherefore, if at a point, &c. Q. E. D.

PROPOSITION XV.

Theorem.—*If two straight lines cut one another, the vertical, or opposite angles shall be equal.*

Let the two straight lines A B, C D cut one another in the point E: the angle AEC shall be equal to the angle D E B and CEB to A E D.

For the angles C E A, A E D, which the straight line A E makes with the straight line C D, are together equal to two right



angles; and the angles A E D, D E B, which the straight line D E makes with the straight line A B, are also together equal to two right angles: therefore the two angles C E A, A E D are equal to the two A E D, D E B. Take away the common angle A E D, and the remaining angle C E A is equal to the remaining angle D E B. In the same manner it can be demonstrated that the angles C E B, A E D are equal. Therefore, if two straight lines, &c. Q. E. D.

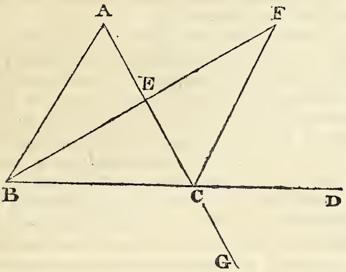
Corollary 1.—From this it is manifest, that if two straight lines cut one another, the angles which they make at the point of their intersection, are together equal to four right angles.

Corollary 2.— And hence, all the angles made by any number of straight lines meeting in one point, are together equal to four right angles.

PROPOSITION XVI.

THEOREM.—*If one side of a triangle be produced, the exterior angle is greater than either of the interior, and opposite angles.*

Let A B C be a triangle, and let its side B C be produced to D, the exterior angle A C D is greater than either of the interior opposite angles C B A, B A C.



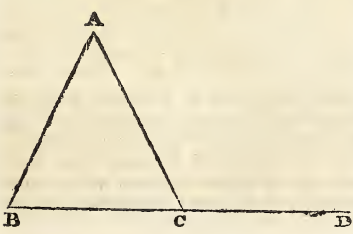
Bisect A C in E, join B E and produce it to F, and make E F equal to BE; join also F C, and produce A C to G.

Because A E is equal to E C, and B E to E F; AE, E B are equal to C E, E F, each to each; and the angle A E B is equal to the angle C E F, because they are vertical angles; therefore the base A B is equal to the base C F, and the triangle A E B to the triangle C E F, and the remaining angles to the remaining angles, each to each, to which the equal sides are opposite; wherefore the angle B A E is equal to the angle E C F; but the angle E C D is greater than the angle E C F; therefore the angle E C D, that is A C D, is greater than B A E: In the same manner if the side B C be bisected, it may be demonstrated that the angle B C G, that is the angle A C D, is greater than the angle A B C. Therefore, if one side, &c. Q.E.D.

PROPOSITION XVII.

THEOREM.— *Any two angles of a triangle are together less than two right angles.*

Let A B C be any triangle; any two of its angles together are less than two right angles.

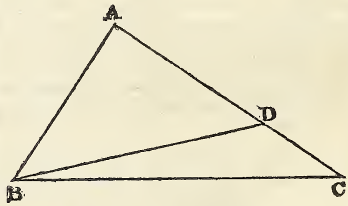


Produce B C to D; and because A C D is the exterior angle of the triangle A B C, A C D is greater than the interior and opposite angle A B C; to each of these add the angles A C B; therefore the angles A C D, A C B are greater than the angles A B C, A C B; but A C D, A C B are together equal to two right angles; therefore the angles A B C, B C A are less than two right angles. In like manner, it may be demonstrated, that B A C, A C B, as also C A B, A B C, are less than two right angles. Therefore any two angles, &c. Q. E. D.

PROPOSITION XVIII.

THEOREM.—*The greater side of every triangle has the greater angle opposite to it.*

Let A B C be a triangle, of which the side A C is greater than the side A B; the angle A B C is also greater than the angle B C A.

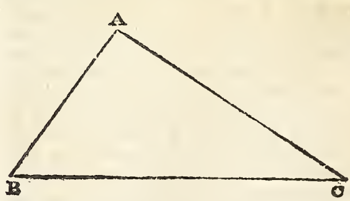


From A C, which is greater than A B, cut off A D equal to A B, and join B D: and because A D B is the exterior angle of the triangle B D C, it is greater than the interior and opposite angle D C B; but A D B is equal to A B D, because the side A B is equal to the side A D: therefore the angle A B D is likewise greater than the angle A C B; wherefore much more is the angle ABC greater than ACB. Therefore the greater side, &c. Q. E. D.

PROPOSITION XIX.

THEOREM.—*The greater angle of every triangle is subtended by the greater side, or has the greater side opposite to it.*

Let A B C be a triangle, of which the angle A B C is greater than the angle

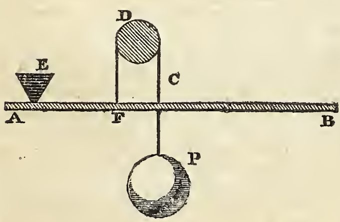


B C A; the side A C is likewise greater than the side A B.

For, if it be not greater, A C must either be equal to A B, or less than it; it is not equal, because then the angle ABC would be equal to the angle A C B; but it is not; therefore A C is not equal to A B; neither is it less; because then the angle A B C would be less than the angle A C B: but it is not: therefore the side A C is not less than A B; and it has been shewn that it is not equal to A B; therefore A C is greater than A B. Wherefore the greater angle, &c. Q. E. D.

MECHANICS.

In the third species of lever the *power* is between the *weight* and the prop. Therefore if the weight and the power in the second kind of lever, be supposed to change places, it will be one of the third kind. Therefore, in order that there may be an equilibrium between the power and the resistance, the intensity of the *power* must exceed the intensity of the *weight*, just as many times as the distance of the *weight* from the prop exceeds the distance of the *power* from it. Thus, let E be the prop of the lever A B,



and W a weight of four pounds, placed three times as far from the prop as the power P acts at F, by the cord C going over the fixed pully D; in this case, the power must be equal to 12 pounds, in order to support the weight.

As this kind of lever is a disadvantage to the moving power, it is never used but in cases of necessity; such as that of a ladder which being fixed at one end, is by the strength of a man's arms reared against a wall. And in clock work, where all the wheels may be reckoned levers of this kind, because the power that moves every wheel, except the first, acts upon it near the centre of motion, by means of a small pinion, and the resistance it has to overcome acts against the teeth, round its circumference.

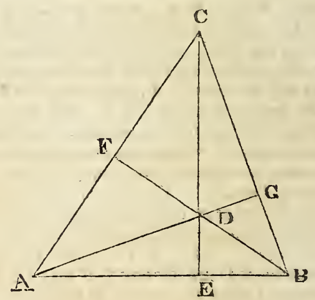
To this sort of lever are generally referred the bones of a man's arm; for when we lift a weight by the hand, the muscle that exerts its force to raise that weight is fixed to the bone about one-tenth part as far below the elbow as the hand is. And the elbow being the centre round which the lower part of the arm turns, the muscle must therefore exert a force ten times as great as the weight that is raised.

By a careful consideration of the different kinds of levers, it will be perceived that in the *first* kind, the *fulcrum*, or prop, is loaded with the *sum* of the forces, that is, with the sum of the weight to be raised, and the power applied to raise it; and in the second and third kind, with the *difference* of these forces.

If we would allow for the *weight* of the lever itself, we must suppose its weight to be united in its centre of gravity, and to act there as a third force, added to the power or the resistance, according to the side of the fulcrum on which it is placed.

If a weight W be sustained on a horizontal plane by three props, (not in a straight line,) the pressure on each will be the same as if a single weight were laid on it, so that the sum of all the three weights were equal to W, and their common centre of gravity the same with the centre of gravity of that body.

Thus, if the props be A, B, C,



and if W be placed with the centre of gravity at D, and if the lines A D G, B D F, C D E, be drawn, the pressure

$$\text{on A is } \frac{DG}{AG} \times W,$$

$$\text{on B is } \frac{DF}{BF} \times W,$$

$$\text{on C is } \frac{DE}{CE} \times W.$$

When the point D coincides with the centre of gravity of the triangle A B C, the pressure on each of the props is the same.

If W be supported by more than three props, the problem appears to be *indeterminate*, or to admit of innumerable solutions.

Nevertheless, if the centre of gravity of the body W, (as it rests on the plane,) be the same with the centre of gravity of the figure made by joining the tops of the props by straight lines, the pressures on the props are all equal to one another.

The lever is the simplest of the mechanical powers, and appears to be the first that was attempted to be explained. Aristotle has treated of it in his Mechanical Questions, and has even endeavoured to reduce some other of the mechanical powers to the lever. The first accurate explanation, however, was given by Archimedes.

The compound lever is, where one lever is made to turn another, and then an *equilibrium* takes place, when the weight is to the power as the product of all the arms, taken alternately beginning with that to which the power is applied, to the product of all the other arms.

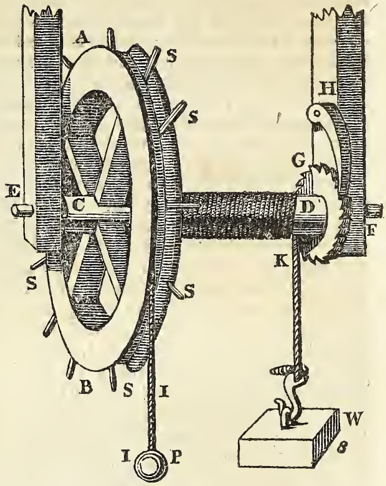
The common apparatus for raising a draw-bridge, is a combination of a lever of the first kind, with a lever of the second; the two levers are parallel, and remain *in equilibrio* in all situations.

It has already been remarked, that the bones of a man's arm form a lever of the third kind: but this mechanical power is much employed in the construction of the animal body. The bone is the lever, the muscle is the power, or rather the medium through which the power acts, and the joint is the fulcrum. The insertion of the muscle, or the point to which the power is applied, is usually nearer the joint or fulcrum than the weight to be raised is. A different structure might have produced more strength, but would have diminished the activity of the animal, and the velocity of its motion.

OF THE WHEEL AND AXLE.

The wheel and axle consists of a wheel having a cylindric axis passing through its centre, and moveable in two grooves. The power is applied to the circumference of the wheel, and the weight to the circumference of the axle. An equilibrium in this instrument takes place when the radius of the wheel, multiplied into the power, is equal to the radius of the axle multiplied into the weight; or when the power and weight are inversely as the radii of the circles to which they are applied.*

Let A B be a wheel, and C D its axle; and suppose the circumference of the wheel to be eight times as great as the circumference of the axle; then, a power P equal to one pound, hanging by the cord I, which goes round the wheel, will balance a weight W, of eight pounds, hanging by the rope K, which goes round the axle. And, as the friction on the pivots or gudgeons of the axle, is but small, as small an addition to the power will cause it to descend, and raise the



weight; but the weight will rise with only an eighth part of the velocity wherewith the power descends, and consequently through no more than an eighth part of an equal space in the same time. If the wheel be pulled round by the handles S, S, the power will be increased in proportion to their length. And by this means, any weight may be raised as high as the operator pleases.

From considering this mechanical power with some attention, it will be discovered that it is nothing else but a lever, so contrived as to have a continued motion about its fulcrum. The principle of the *virtual velocities* is here obviously applicable, (see page 55, col. 2.) If the power acts not at the circumference of the wheel, but at the extremity of a hand-spike inserted in the wheel, the distance of that extremity from the centre of the axis is to be accounted the radius of the wheel. To this sort of engine belong all cranes for raising great weights, and in this case, the wheel may have cogs all round it instead of handles, and a small lantern or trundle may be made to work in the cogs, and be turned by a winch; which will make the power of the engine to exceed the power of the man who works it, as much as the number of revolutions of the winch exceed those of the axle D, when multiplied by the excess of the length of the winch above the length of the semidiameter of the axle, added to the semi-

* It is supposed here, that the power and the weight both act at right angles to the radius.

diameter or half thickness of the rope K, by which the weight is drawn up. Thus, suppose the diameter of the rope and axle taken together, to be 12 inches, and consequently, half their diameters to be six inches, so that the weight W will hang at six inches perpendicular distance from below the centre of the axle. Now, let us suppose the wheel A B, which is fixed on the axle, to have 80 cogs, and to be turned by means of a winch six inches long, fixed on the axis of a trundle of eight staves or rounds, working in the cogs of the wheel. Here it is plain that the winch and trundle would make ten revolutions for one of the wheel A B, and its axis D, on which the rope K winds in raising the weight W; and the winch being no longer than the sum of the semidiameters of the great axle and rope, the trundle could have no more power on the wheel, than a man could have by pulling it round by the edge; because the winch would have no greater velocity than the edge of the wheel has, which we here suppose to be ten times as great as the velocity of the rising weight; so that, in this case, the power gained would be as ten to one. But if the length of the winch be twelve inches, the power gained will be as twenty to one: if eighteen inches (which is long enough for any man to work by) the power gained would be as thirty to one; that is, a man could raise 30 times as much by such an engine as he could do by his natural strength without it, because the velocity of the handle of the winch would be 30 times as great as the velocity of the rising weight; the absolute force of any engine being in proportion of the velocity of the power to the velocity of the weight raised by it. But then, just as much power or advantage as is gained by the engine, so much time is lost in working it. In machines of this sort it is requisite to have a racket wheel G on one end of the axle, with a catch H to fall into its teeth; which will at any time support the weight, and keep it from descending, if the workman, through inadvertency or carelessness, quit his hold whilst the weight is raising. And by this means, the danger is prevented which might otherwise happen by the running down of the weight when left at liberty.

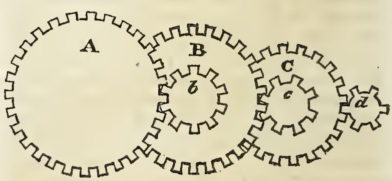
The *capstan*, the *windlass*, and other contrivances of a similar nature, are nothing else than the wheel and axle adapted to particular circumstances.

The mechanical contrivance called a *crank*, is a species of wheel and axle. If the force which acts upon a crank presses it directly down and up alternately, the effect, compared with what would take place if the force acted at right angles to the arm of the crank all round, is as twice the diameter of a circle to its circumference, or as seven to eleven nearly.

The combination of wheels, so useful in mechanics, are generally reducible to the wheel and axle, the wheel which turns the other is not always upon the same axis with it. The motion, in such cases, is communicated from the one wheel to the other, either by belts and straps passing over the circumference of both, or by teeth cut in the circumference of each, and working in one another.

When one wheel moves another in either of these ways, the velocities of their circumferences are equal; and therefore their angular velocities, or the number of revolutions which they make in the same time, are inversely as their radii.*

In combination of wheels communicating motion to one another, it is usual to call the smaller wheel, acted on by a larger one, a *pinion;* and the teeth the *leaves* of it. Sometimes the smaller wheel is a cylinder, in which the top and bottom are formed by circles connected by staves inserted in them at equal distances along their circumferences; and it is then called a *lantern*, the staves serving for teeth. It is usual also to employ the wheels and pinions, as in the following figure,



where A is a large wheel, driving a pinion *b* on the same axle with the great wheel B; B acts on the pinion *c*, which is on the same axle with the large wheel C: and C drives the pinion *d*, &c.

When motion is communicated through a number of wheels and pinions, the angular velocity of the first wheel is to the angular velocity of the last pinion, as the product made by multiplying together the number of the teeth in every pinion, to the product made by multiplying together the number of the teeth in every wheel; and that same ratio, compounded with the ratio of the radius of the last pinion, to the radius of the first wheel, will give the ratio of the power to the resistance when an equilibrium takes place.

Suppose the wheel A to contain 40, B 30, and C 20 teeth; and the pinion *b* 10, *c* 8, and *d* 5 teeth, required the number of re-

* That is, the larger the wheel, the fewer revolutions will it make.

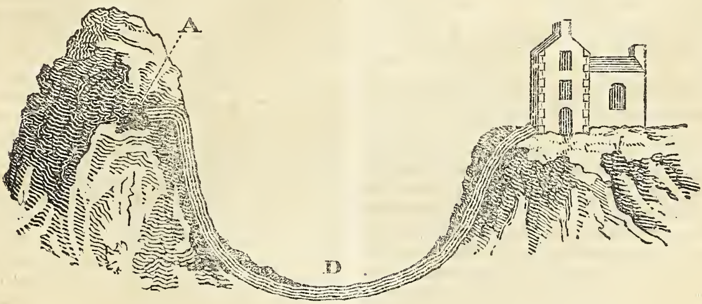
volutions made by the last pinion *d*, in the time of the first wheel A making one revolution?

Here $\frac{40 \times 30 \times 20}{10 \times 8 \times 5} = 60$, the number required. Again, to illustrate the latter part of the proposition; suppose the radius of this pinion (*d*) to be 3 inches, and that of the wheel 9 inches, required the ratio of the power to the resistance, when an equilibrium takes place? The ratio of the pinion's velocity being to that of the wheel as 60 to 1, and the ratio of its radius to that of the wheel is $\frac{3}{9}$, or 1 to 3; therefore $(60 \times 1) \div 3 = 20$; consequently the power is to the resistance as 1 to 20, or a power one-twentieth part of the resistance, will in this case produce an equilibrium.

HYDRAULICS.*

The pressure of fluids affords the means of conveying them from one place to another, although considerable inequalities in the surface of the ground intervene between the places. Water, for example, may be conveyed from a reservoir across a valley, or to any distance, either by means of open canals, aqueducts, or closed pipes, provided the reservoir be situated somewhat higher than the level of the place at which it is wanted.

Thus, suppose there is a spring at A,



on one side of the valley D, and a house on the other, at which the water of the spring is wanted; if the house is found to be lower than the spring, the water may be conveyed to it, by an iron or leaden pipe, proceeding from the spring, across the valley, as represented in the above figure.

The depth of the valley must, however, be taken into consideration, in order to make the pipe of sufficient strength to resist the pressure of the water, which depends entirely on its depth (see page 9, col. 1.) If the lowest part of the valley be considerably under the spring, the pipe must be made very strong at the lowest part, or else it will burst.

Where an uninterrupted declivity cannot be obtained, it is necessary to employ pipes, which may be bent upwards or downwards at pleasure, provided that no part of them be more than thirty-two feet above the reservoir, and when the pipe is once filled, the water will continue to flow from the lower orifice; but it is best in all such cases to avoid unnecessary angles; for when the pipe rises and falls again, a portion of the air, which is always contained in water, is frequently collected in the angle, and very materially impedes the progress of the water through the pipe. When the bent part is wholly below the orifices of the pipe, this air may be discharged by various methods. The ancients used small upright pipes, called *columnaria*, rising from the convexity of the principal pipe to the level of the reservoir, and suffering the air to escape without wasting any of the water. It may, however, frequently be inconvenient or impossible to apply a pipe of this kind; but the same purpose may be answered, by fixing on the pipe a box containing a small valve, which opens downwards, and is supported by a float, so as to remain shut while the box is

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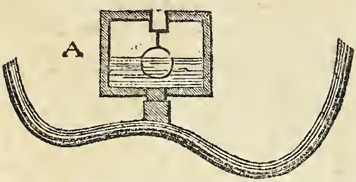
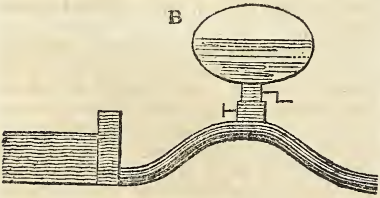
* Hydraulics is that branch of Hydrodynamics which treats of the motion of incompressible fluids, and the instruments and machines connected with their motion (see page 8). This division of the science commenced with the account of fluids issuing through apertures, at page 57, but by mistake was neglected to be inserted.

full of water, and to fall open when any air is collected in it. Thus A, in the following figure, is a box of this kind, with a valve, supported by a hollow ball, for letting out air from pipes, when it is below the level of the reservoir.

If the pipe were formed into a syphon, having its flexure above both orifices, it would be necessary to bend it upwards at the extremities, in order to keep it always full; but in this case the accumulation of the air would be extremely inconvenient, since it would collect so much the more copiously, as the water in the upper part of the pipe would be more free from pressure; and neither of the methods which



have been mentioned would be of any use in extricating it. It has been usual in such cases to force a quantity of water violently through the pipe, in order to carry the air with it; but it might be still simpler to have a pretty large vessel of water screwed on to the pipe, which would not be filled with air for a considerable time, and which, when full, might be taken off and replenished with water. This contrivance is represented by the following figure, where B is a vessel of water, screwed on for receiving the air, to be replenished with water as it becomes empty.



When the water from a reservoir is conveyed in long horizontal pipes, of the same aperture, the discharges made in equal times are nearly in the inverse ratio of the square roots of the lengths.

Thus, if there be two pipes of the same aperture, one of which is 49, and the other 36 feet long, the discharge from the former will be to that from the latter, as the square root of 49 to the square root of 36, or as 7 to 6; therefore, the quantity discharged from the shorter pipe will be $\frac{7}{6}$ of that discharged from the larger one. It is here supposed that the length of the pipes to which this rule is applied, are not very unequal; and even then the rule only affords an approximation not deduced from principle, but derived immediately from experiment. Bossut has given a table of the actual discharges of water pipes, as far as the length of 2340 toises, or 14950 English feet, but it is too extensive to be inserted here.

If the quantity of water discharged by a pipe of a given length, be known by experiment, we may find, by the foregoing proposition, the quantity discharged by a pipe of any other length. The diminution of velocity being greatest when the head of water is small, we may conceive the head of water to be reduced to such a degree, that the velocity with which the water enters the pipe is not sufficiently powerful to overcome the resistance arising from the friction upon the pipe, and the mutual cohesion of the particles of water.* In order to examine this point experimentally, M. Bossut employed a head of water only 16 lines, from which the water flowed into two pipes whose length were a hundred and eighty feet.† In this case, the water was discharged in the form of a narrow fillet, and the drops succeeded each other almost as if they were insulated bodies. Hence it follows, that in order to have a perceptible and continuous discharge from pipes, there should be a head of water of about 20 lines in 180 feet. If the current of water, however, be very large, such a great declivity as this will not be necessary.

Pipes are usually made of wood, of lead, or of cast iron; but commonly of lead: and of late tinned copper has been employed with considerable advantage. A pipe of lead will bear the pressure of a column of water 100 feet high, if its thickness be one hundredth of its diameter, or even less than this; but when any alternation of motion is produced, a much stronger pipe is required: and it is usual to make leaden pipes of all kinds far thicker than in the above proportion.

The form and construction of *stopcocks* and *valves* are very various, according to their various situations and uses. *Stopcocks* usually consist of a cylindrical or conical part, perforated in a particular direction,

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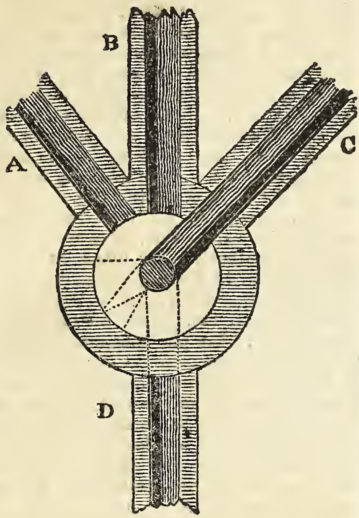
* By a head of water is meant the perpendicular depth of the water in the reservoir above the axis or centre of the pipe by which it is discharged.

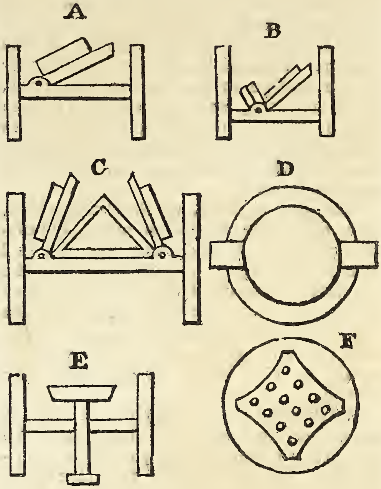
† A Line is the one-twelfth of a Paris inch, and is equal to ·0888 of an English inch.

and capable of being turned in a socket formed in the pipe, so as to open or shut the passage of the fluid, and sometimes to form a communication with either of two or more vessels at pleasure.

The following figure is a section of a compound stopcock, which receives a fluid from either of the pipes A, B, or C, into a cavity which descends a little in the direction of the axis, and communicates with the pipe D by means of one of the bores, represented by dotted lines, according to the position into which the moveable cylinder is turned.



A *valve* is employed where the fluid is to be allowed to pass in one direction only, and not to return. For *water*, those valves are the best which interrupt the passage least; and none appear to fulfil this condition better than the common *clack* valve of leather, which is generally either single, or divided into two parts; but it is sometimes composed of four parts, united so as to form a pyramid, nearly resembling the double and triple valves which are formed by nature in the hearts of animals. A board, or a round flat piece of metal, divided unequally by an axis on which it moves, makes also a very good simple valve. Where a valve is intended to intercept the passage of *steam*, it must be of metal; such a valve is generally a flat plate, with its edge ground a little conically, and guided in its motion by a wire or pin. For *air*, valves are commonly made of oiled silk, supported by a perforated plate or grating. The following are among the most common and approved kinds of valves.



The figure A is the common clack valve: B, a double clack valve, consisting of two semicircular valves; C, a pyramidical valve, consisting of four triangular pieces; D, a circular valve, turning on an axis; E, a steam valve of metal, sometimes called a T valve; F, a valve of veiled silk or bladder, supported by a grating for air.

Water running in open canals or in rivers, is accelerated in consequence of its depth, and the declivity on which it runs, till the resistance, increasing with the velocity, becomes equal to the acceleration, and then the motion of the stream becomes uniform.

It must however be evident, that the amount of the resisting forces can hardly be determined by principles already known, and therefore it becomes necessary to ascertain, by experiment, the velocity corresponding to different declivities, and different depths of water, and to try, by multiplying and extending these experiments, to find out the law which is common to them all.

The Chevalier Du Buat has been very successful in researches of this kind, and has given a formula for computing the velocity of running water, whether in close pipes, open canals, or rivers, which, though it maybe called *emperical*, is extremely useful in practice; but it is by far too complicated to be given in a work like the present.

In a river, the greatest velocity is at the surface, and in the middle of the stream, from which it diminishes towards the bottom and the sides, where it is least. It has been found by experiment, that if from the square root of the velocity in the middle of the stream, expressed in inches *per second*, *unity* be subtracted, the square of the remainder is the velocity at the bottom. Thus, if the velocity of the water at the surface in the middle of a river, be 25 inches per second, the velocity at the bottom will be 16 inches; for the square root of 25 is 5, and 5 diminished by unity or 1, leaves a remainder of 4, which squared is 16.

The *mean* velocity, or that with which, were the whole stream to move, the discharge would be the same with the *real* discharge, is equal to half the sum of the greatest and least velocities at the surface and bottom, as computed by the proposition just mentioned, and consequently in the example now given, the mean velocity would be $25 + 16 \div 2$, or $20\frac{1}{2}$ inches per second.

When the water in a river receives a permanent increase, the depth and the velocity are the first things that are augmented. The increase of the velocity increases the action on the sides and bottom, in consequence of which the width is augmented, and sometimes also, but more rarely, the depth. The velocity is thus diminished, till the tenacity of the soil, or the hardness of the rock, over which it passes, affords a sufficient resistance to the force of the water. The bed of the river then changes only by imperceptible degrees, and, in the ordinary language of Hydraulics, is said to be permanent, though in strictness this epithet is not applicable to the course of any river.

Miscellaneous Subjects.

BIOGRAPHICAL MEMOIR OF THOMAS SIMPSON.

Mr. Thomas Simpson was born at Market Bosworth, in the county of Leicester, August the 20th, O. S. 1710. His father was a stuff-weaver in that town; and, though in tolerable circumstances, yet, intending to bring up his son Thomas to his own business, he took so little care of his education, that he was only taught to read English. But nature had furnished him with talents, and a genius for very different pursuits, which led him afterwards to the highest rank in the mathematical and philosophical sciences.

Young Simpson very soon gave indications of his turn for study in general, by eagerly reading all books he could meet with, teaching himself to write, and embracing every opportunity he could find of deriving knowledge from other persons. Thomas's father observing him thus to neglect his business, by spending his time in reading what he thought useless books, and following other such like pursuits, used all his endeavours to check such proceeding, and to induce him to follow his profession with steadiness and better effect. But after many struggles for this purpose, the differences thus produced between them at length rose to such a height, that our Author quitted his father's house entirely.

Upon this occasion he repaired to Nuneaton, a town at a small distance from Bosworth, where he went to lodge at the house of a taylor's widow, of the name of Swinfield, who had been left with two children, a daughter and a son, by her husband, of whom the son, who was the younger, being but about two years older than Simpson, had become his intimate friend and companion. And here he continued some time, working at his trade, and improving his knowledge by reading such books as he could procure.

Among several other circumstances, which, long before this, gave occasion to shew our author's early thirst for knowledge, as well as proving a fresh incitement to acquire it, was that of a large solar eclipse, which took place on the 11th of May 1724. This phenomenon, so awful to many, who are ignorant of the cause of it, struck the mind of young Simpson with a strong curiosity to discover the reason of it, and to be able to predict the like surprising events. It was however five or six years before he could obtain his desire, which at length was gratified by the following accident. After he had been some time at Mrs. Swinfield's, at Nuneaton, a travelling pedlar came that way, and took a lodging at the same house, according to his usual custom. This man, to his profession of an itinerant merchant, had joined the more profitable one of a fortune-teller, which he performed by means of judicial astrology. Every one knows with what regard persons of such a cast are treated by the inhabitants of country villages: it cannot be surprising therefore that an untutored lad of nineteen should look upon this man as a prodigy; and, regarding him in this light, should endeavour to ingratiate himself into his favour; in which he succeeded so well, that the sage was no less taken with the quick natural parts and genius of his new acquaintance. The pedlar, intending a journey to Bristol fair, left in the hands of young Simpson an old edition of Cocker's Arithmetic, to which was subjoined a short Appendix on Algebra, and a book upon Genitures, by Partridge the almanac maker. These books he had perused to so good purpose, during the absence of his friend, as to excite his amazement upon his return.

In fact, our author profited so well by the encouragement and assistance of the pedlar, afforded him from time to time when he occasionally came to Nuneaton, that, by the advice of his friend, he at length made an open profession of casting nativities himself; from which, together with teaching an evening school, he derived a pretty pittance, so that he greatly neglected his weaving, to which indeed he had never manifested any very great attachment, and soon became the oracle of Nuneaton, Bosworth, and the environs. Scarce a courtship advanced to a match, or a bargain to a sale, without previously consulting the infallible Simpson about the consequences. But helping folks to stolen goods, he always declared above his skill; and that as to life and death, he had no power: all those called *lawful questions*, he readily resolved, provided the persons were certain as to the horary *data* of the horoscope; and, he has often declared, with such success, that if from very cogent reasons he had not been thoroughly convinced of the vain foundation and fallaciousness of his art, he never should have dropt it, as he afterwards found himself in conscience bound to do.

About this time he married the widow Swinfield, in whose house he lodged, though she was then almost old enough to be his grandmother, being upwards of fifty years of age, and having been looked upon as an old maid before her first marriage: and yet her youngest child was two years older than Simpson himself. After this, the family lived comfortably enough together for some short time, Simpson occasionally working at his business of a weaver in the day-time, and teaching an evening school or telling fortunes at night; the family being also further assisted by the labours of young Swinfield, who had been brought up in the professioon of his father. But this tranquillity was soon interrupted, and our author driven at once from his home and the profession of astrology, by the following accident. A young woman in the neighbourhood had long wished to hear or know something of her lover, who had been gone to sea; but Simpson had put her off from time to time, till the girl grew at last so importunate, that he could deny her no longer. He asked her if she would be afraid if he should raise the devil, thinking to deter her; but she deelared she feared neither ghost nor devil, so he was obliged to comply. The scene of action pitched upon was a barn, and young Swinfield was to act the devil or ghost, who, being concealed under some straw in a corner of the barn, was, at a signal given, to rise slowly out from among ths straw, with his face marked so that the girl might not know him. Every thing being in order, the girl came at the time appointed; when Simpson, after cautioning her not to be afraid, began muttering some mystical words, and chalking round about them, till, on the signal given, up rises the tailor, slow and solemn, to the great terror of the poor girl, who, before she had seen half his shoulders, fell into violent fits, crying out it was the very image of her lover; and the effect upon her was so dreadful, that it was thought either death or madness must be the consequence. So that poor Simpson was obliged immediately to abandon at once both his home and the profession of a conjuror.

Upon this occasion it would seem he fled to Derby, where he remained about two or three years, instructing pupils in an evening school, and working at his trade by day. Here too he wrote a song on occasion of the parliamentary election at this place, in the year 1733, in favour of the Cavendish family: and it is probable he continued here till about the year 1735 or 1736.

It would seem indeed that Simpson had an early turn for versifying, both from the circumstance of the song abovementioned, and from his first two mathematical questions that were published in the Ladies' Diary, which were both in a set of verses, not ill written, for the occasion. These were printed in the Diary for 1736, and therefore must at latest have been written in the year 1735. These two questions, being at that time pretty difficult ones, shew the great progress he had even then made in the mathematics; and from an expression in the first of them, viz. where he mentions his residence as being in latitude 52°, it appears he was not then come up to London, though he must have done so very soon after.

Together with his astrology he had soon furnished himself with enough of arithmetic, algebra, and geometry to be qualfied for looking into the Ladies' Diary (of which he had afterwards for several years the direction), by which he came to understand that there was a still higher branch of mathematical knowledge than any he had yet been acquainted with; and this was the method of *Fluxions*. But our young analyst was quite at a loss to discover any English author who had written on the subject, except Mr. Hayes; and his work being a folio, and then pretty scarce, exceeded his ability of purchasing: however, an acquaintance lent him Mr. Stone's *Fluxions*, which is a translation of the *Marquis de l'Hospital's Analyse des Infiniment Petits:* by this one book, and his own penetrating talents, he was, as we shall presently see, enabled in a very few years to compose a much more accurate treatise on this subject than any that had before appeared in our language.

After he had quitted astrology and its emoluments, he was driven to hardships for the subsistence of his family, while at Derby, notwithstanding his other industrious endeavours in his own trade by day, and teaching pupils at evenings. This determined him to repair to London, which he did in 1735 or 1736, as before said, leaving the family behind, his wife being then pregnant with her first child by our Author, which was contrary to the expectation of every one, being then about fifty-five years of age, for which reason her neighbours used to say, " there goes Sarah the wife of Abraham.

On his first coming to London, Mr. Simpson wrought for some time at his business in Spitalfields, and taught mathematics at evenings, or any spare hours. His industry turned to so good account, that he returned down into the country, and brought up his wife and three children, she having produced her first child in his absence. The number of his scholars increasing, and his abilities becoming in some measure known to the public, he was encouraged to make proposals for publishing by subscription, *A new Treatise of Fluxions; wherein the Direct and Inverse Method are demonstrated after a new, clear, and concise Manner, with their Application to Physics and Astronomy: also the Doctrine of Infinite Series and Reverting Series universally, are amply explained, Fluxionary and Exponential Equations solved; together with a variety of new and curious Problems.*

When Mr. Simpson first proposed his intentions of publishing such a work, he did not know of any English book, founded on the true principles of Fluxions, that contained any thing material, especially the practical part: and though there had been some very curious things done by several learned and ingenious gentlemen, the principles were nevertheless left obscure and defective, and all that had been done by any of them in *infinite series,* very inconsiderable.

The book was published in 4to, in the year 1737, although the author had been frequently interrupted from furnishing the press so fast as he could have wished, through his unavoidable attention to his pupils for his immediate support. The principles of fluxions treated of in this work, are demonstrated in a method accurately true and genuine, not essentially different from that of their great inventor, being entirely expounded by finite quantities. In the first and second parts are given a great many new, and some very curious examples in the solutions of problems, rendered plain to ordinary capacities.

The second part treats of *Infinite Series.* And here nothing is proposed without demonstration, and every thing is illustrated by easy examples. New rules are also laid down for finding the forms of series, without taking in any of the superfluous terms.

The third part contains a familar method of finding and comparing fluents, illustrated with some useful and easy applications.

In the fourth part is shewn the use of fluxions in some of the most sublime branches of *Physics* and *Astronomy;* where, besides several things done in a method quite different from any thing to be met with in other authors, there are some very useful speculations relating to the doctrine of Pendulums and Centripetal Forces.

To this is added a supplement; being a collection of miscellaneons problems, independent of the foregoing four parts; and containing, among other matters, an investigation of the Areas of Spherical Triangles; the Curve of Pursuit; the Paths of Shadows; the Motion of Projectiles in a Medium; and the manner of finding the Attractive Force of bodies of different forms, acting according to a given law.

In 1740 Mr. Simpson published a treatise on the Nature and Laws of Chance, in 4to. To which is annexed, Full and clear Investigations of two important Problems added in the 2d edition of Mr. De Moivre's book on chances: as also two New Methods for the Summation of Series.

Our author's next publication was a 4to volume of Essays on several curious and interesting Subjects in Speculative and Mixed Mathematics; printed in the same year, 1740: dedicated to Francis Blake, Esq. since Fellow of the Royal Society, and our author's good friend and patron.

The first of these essays shews the theory of the apparent place of the stars (commonly called their *Aberration*) arising from the progressive motion of light, and of the earth in its orbit; with practical rules for computing the same, communicated by Dr. Bevis.

The second treats of the Motion of Bodies affected by projectile and centripetal forces; in which the most considerable matters in the first book of Newton's Principia are clearly investigated.

The 3d is a Solution of Kepler's Problem, with a concise practical rule.

The 4th treats of the Motion and Paths of Projectiles in resisting mediums; determining the most important particulars upon this head, in the 2d Book of the Principia.

The 5th considers the Resistances, Velocities, and Times of Vibration of Pendulous Bodies in Mediums.

The 6th contains a new method of Solution of all kinds of algebraical equations in numbers, more general than ever before given.

The 7th is concerning the method of Increments, with examples.

The 8th is a concise Investigation of a Theorem for finding the Sum of a Series of Quantities, by means of their Differences.

The 9th is a general way of investigating the Sum of a recurring Series.

The 10th is a new and general method for finding the Sum of any Series of Powers, whose roots are in arithmetical progression; being also applicable to Series of other kinds.

The 11th relates to angular Sections, with some remarkable properties of the circle.

The 12th shews an easy and expeditious method of reducing compound Fractions to simple ones.

The 13th, or last, which contains a general Quadrature of hyperbolical Curves, is a problem that had exercised the skill of several eminent mathematicians. None of the solutions before published extended farther than to particular cases, except one, which is in the Philosophical Transactions, without demonstration, by Mr. Klingenstierna, professor of mathematics at Upsal. This is investigated by Mr. Simpson in two different ways; and the general construction is rendered remarkably easy, simple, and fit for practice. And, on this head, it would seem that Mr. Klingenstierna was well pleased with what Mr. Simpson had done; for, being afterwards appointed Secretary to the Royal Academy at Stockholm, as a mark of his esteem, he procured a diploma, to be transmitted to him, by which he was constituted a member of that learned body.

Our author's next work was, The Doctrine of Annuities and Reversions, deduced from general and evident Principles; with useful Tables, shewing the Values of Single and Joint Lives, &c. in 8vo. 1742. This was followed in 1743, by an Appendix, containing some Remarks on a late Book on the same Subject (by Mr. Abr. De Moivre, F. R. S.) with Answers to some personal and malignant representations in the preface thereof. To this answer Mr. De Moivre never thought fit to reply. A new edition of this work has lately been published, augmented with the tract upon the same subject that was printed in our author's Select Exercises.

In 1743 also was published his Mathematical Dissertations on a variety of Physical and Analytical Subjects, in 4to. containing, among other particulars,

A demonstration of the true figure, which the earth or any planet must acquire from its rotation about an axis. A general investigation of the attraction at the surfaces of bodies nearly spherical. A determination of the meridional parts, and the lengths of the several degrees of the meridian, according to the true figure of the earth. An investigation of the height of the tides in the ocean. A new theory of astronomical refractions, with exact tables deduced from the same. A new and very exact method for approximating to the roots of equations in numbers: which quintuples the number of places at each operation. Several new methods for the summation of series. Some new and very useful improvements in the inverse method of fluxions. The work being dedicated to Martin Folkes, Esq. President of the Royal Society.

His next book was a treatise of algebra, wherein the fundamental Principles are demonstrated, and applied to the solution of a variety of Problems. To which he added, the Construction of a great Number of Geometrical Problems, with the Method of resolving them numerically.

This work, which was designed for the use of young beginners, was inscribed to William Jones, Esq. F. R. S. and printed in 8vo. 1745. And a new edition appeared in 1755, with additions and improvements; among which was a new and general method of resolving all biquadratic equations, that are complete, or having all their terms. This edition was dedicated to James, Earl of Morton, F. R S. Mr. Jones being then dead. The work has gone through several other editions since that time; the 6th, or last, was in 1790.

His next work was, Elements of Geometry, with their Application to the Mensuration of Superfices and Solids, to the determinasion of Maxima and Minima, and to the Construction of a great Variety of Geometrical Problems; first published in 1747, in 8vo. And a second edition of the same came out in 1760, with great alterations and additions, being in a manner a new work, designed for young beginners, particularly for the gentlemen educated at the Royal Military Academy at Woolwich, and dedicated to Charles Frederick, Esq. Surveyor General of the Ordnance. And other editions have appeared since.

Mr. Simpson met with some trouble and vexation in consequence of the first edition of his Geometry. First, from some reflections made upon it, as to the accuracy of certain parts of it, by Dr. Robert Simson, the learned professor of mathematics in the university of Glasgow, in the notes subjoined to his edition of Euclid's Elements. This brought an answer to those remarks from Mr. Simpson, in the notes added to the 2d edition as above; to some parts of which Dr. Simson again replied, in his notes on the next edition of the said Elements of Euclid.

The second was by an illiberal charge of having stolen his Elements from Mr. Muller, the professor of fortification and artillery, at the same academy at Woolwich, where our author was professor of geometry and mathematics. This charge was made at the end of the preface to Mr. Muller's Elements of Mathematics, in two volumes, printed in 1748.

But Mr. Simpson triumphantly refuted this charge in the preface to the second edition.

In 1748 came out Mr. Simpson's Trigonometry, Plane and Spherical, with the Construction and Application of Logarithms, 8vo.

In 1750 came out, in two volumes, 8vo. The Doctrine and Application of Fluxions; containing, besides what is common on the Subject, a Number of new Improvements in the Theory, and the Solution of a variety of new and very interesting Problems in different Branches of the Mathematics.

In 1752 appeared, in 8vo. The Select Exercises for young Proficients in the Mathematics.

Besides the foregoing, which are the whole of the regular books or treatises that were published by Mr. Simpson, he wrote and composed several other papers and fugitive pieces.

Several papers of his were read at the meetings of the Royal Society, and printed in their Transactions: but as most, if not all of them, were afterwards inserted, with alterations, or additions, in his printed volumes, it is needless to take any farther notice of them here.

[*To be continued.*]

NEW MACHINE FOR MAKING BREAD.

A machine has just been introduced at Lausanne, for making bread; that is, for promoting the fermentation of the dough, which appears from its ingenuity to deserve being adopted in other countries. It is simply a deal box one foot high, and two feet wide, which turns round on two pivots, precisely in the same manner as the cylinder which is used for roasting coffee. One side of the box can be opened to put in the dough. The time required to produce the fermentation depends on the temperature of the air, the quickness of the motion, and other circumstances; but when the operation is completed, it can always be known by the hissing of the air, which endeavours to escape, and this generally takes place in half an hour. The dough is always very well raised, perhaps sometimes too much so. A child can turn the machine. There is no necessity for employing utensils to divide the mass of dough, this operation being sufficiently effected by the adhesion of the dough to the sides of the box. If the machine is of great length, and divided by partitions at right angles to the sides, different kinds of dough can be prepared at the same time. One evident advantage belonging to this invention is, that the bread prepared in this manner must necessarily be extremely clean.

TO PREPARE AN OIL FOR CLOCKS, AND OTHER DELICATE MACHINERY.

The oil for diminishing friction in delicate machines, ought to be completely deprived of every kind of acid and mucilage: and to be capable of enduring a very intense degree of cold without freezing. In fact, it ought to consist entirely of *elaine* or the *oily* principle of solid fat, and to be perfectly free from *stearine* or *solid fat*.

Now it is not a difficult matter to extract the *ealine* from all the fixed oils, and even from seeds, by the process recommended by Chevreul, which consists in treating the oil in a mattras with seven or eight times its weight of alchol till boiling. The liquid is then to be decanted, and exposed to the cold, the *stearine* will then separate from it in the form of a crystallized precipitate. The alcholic solution is afterwards to be evaporated to a fifth part of its volume, and the *elaine* will then be obtained, which ought to be colourless, insipid, without smell, and incapable of altering the colour of the infusion of litmus or turnsole, and having the consistence of pure white olive oil.

CONJECTURES UPON THE UNION OF THE MOON WITH THE EARTH.

A curious pamphlet has lately been published in Paris, by an officer of the navy, in which he attempts to render it probable that, not only the moon, or satellite of the earth, but the satellites in general, may, at some future period, unite with their *primaries*.

To support this hypothesis, he attempts to explain the cause and effects of the deluge, the varieties which formerly existed among living and organic bodies, the sudden appearance or formation of other new species, and even for man himself on the terrestrial globe.

The author supposes that the satellites were formerly small planets, which revolved like the other primary planets, round the sun; that in an infinite number of revolutions, this motion, by some unknown cause, has undergone very great alterations, which has brought them near to other planets, much greater than themselves, and whose attraction has become preponderant. By this means these small planets have been drawn from their primitive orbits to circulate round greater ones.

This effect is attributed chiefly to the action of comets.

Applying this hypothesis to the moon, the author thinks that these bodies have produced an effect of this kind upon that body, and dashed it against our globe, or at least, coming suddenly near it, caused such a dreadful concussion, as to throw down the mountains, raise the vallies, rupture the isthmuses, displace the sea, &c. He even supposes that the waters of the moon and its atmosphere, have been carried off by the earth, or else its diversified regions would have been suddenly overflown.

We shall not follow the author in all the consequences of his hypothesis. The field of conjecture, as he says himself, is vast, but till a supsosition has been submitted to the test of experiment or calculation, it cannot be regarded as an established truth.

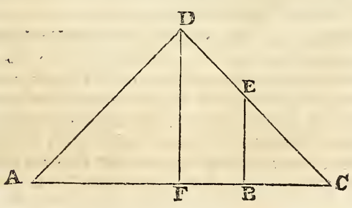
As to the rest of the work, the lovers of this kind of speculation may read it with pleasure; and the whole is certainly the work of a friend to the sciences, many parts of which he appears to have studied with success.

SOLUTION OF QUESTIONS.

To the Editor of the Artisan.

Sir.—Being a constant reader of your excellent publication, I have seen several curious and useful philosophical questions in the 2d and 3d Numbers, and being a little acquainted with calculation, I have devoted a leisure hour to the solution of the two questions by your correspondent Rerum, and inserted in the 3d Number of the Artisan. A Carpenter.

Example 1:—Put B E, in the annexed figure, equal to



the difference of the heights of the walls $(=6\frac{3}{4})=a$; B A the breadth of the house $(=28)=b$; A D (= D C) the length of the *rafters* (= 24 feet) $=c$, and B C $=x$; then drawing D F parallel to E B, F C will be $=\frac{b+x}{2}$, and EC $=\sqrt{a^2+x^2}$, and by the property of similar triangles,

$$x\,(BC):\sqrt{a^2+x^2}\,(EC)::\frac{b+x}{2}\,(FC):c$$

(D C); therefore, $\sqrt{a^2+x^2}=\frac{2\,c\,x}{b+x}$, and this resolved gives x (B C) = 7·345, and hence D E, the length of the back rafters are found to be 14·02288 feet nearly.

Ex. 2.— The content of the whole ring is $=\cdot1^2\times\cdot785398\times\cdot8\times3\cdot141592$ or ·0197392; and the content of the outer or golden part is $=.1^2\times\frac{\cdot785398}{2}\times\cdot85\times3\cdot141592$, or ·0104864, which subtracted from ·0197392, the content of the whole, leaves the inner, or silver part, = 0092528; then as 1728 inches is to ·0104864 of an inch, so is $18\cdot888\times\frac{3501}{3840}$ oz. troy, to ·104503188 oz. troy gold, which at £3. 17*s.* 10½*d.* per oz. is 8*s.* 1½*d.*—$\frac{6}{10}$; and as 1728 inches is to ·0092528, so is $\cdot10535\times\frac{3501}{3840}$ to ·05143098 of an inch silver, which at 5s. 2*d.* per oz.

	s.	*d.*	
is . .	0	3 —$\frac{7}{10}$	value of silver,
and	8	1½—$\frac{6}{10}$	do. of gold,
also	5	0	expense of making.
	13	4¾—$\frac{3}{10}$	whole value.*

The last of the above questions was also answered by Mr. Richard Graham, Ranelagh-street, Liverpool, but he will perceive that he has mistaken the specific gravity of standard gold and silver, for *pure* gold and silver; he will also perceive that he has employed the proportion between the *pound* troy and avoirdupois, instead of the *oz.*

The oz. troy contains 480 grains, and the oz. avoirdupois only 437⅝; and consequently are to each other as the number 3840 to 3501. The troy pound contains 5760 grains, and the pound avoirdupois 7002; these *pounds* are, therefore, to each other as the number 2880 to 3501; but the oz. is in the above proportion. Edit.

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* The fraction $\frac{3501}{3840}$ denotes the proportion which the oz. troy bears to the oz. avoirdupois.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR.—By inserting the following question in one of the future numbers of the "Artisan," you will oblige your constant reader,

CHARON.

If the specific gravity of brandy be 886, and that of sea-water 1030; and if a person having a cask half full of brandy, which when full would contain 10 gallons, throws it overboard, for the purpose of concealment: required what weight of *lead* is just sufficient to keep it under water, if the wood of the cask measures 216 cubic inches?

To the Editor of the Artisan.

SIR.—Please to insert the following question in your next, if convenient, which will oblige your obedient servant,

RICHARD GRAHAM.

Ranelagh-street, Liverpool.

There is a circular plot of ground to be divided into four shares; the areas of which are as 1, 2, 3, 4, respectively, by straight lines, terminating in a pond, whose outer fences are to be quadrants: required the situation of the pond, that all the shares may receive the benefit of the water?

To the Editor of the Artisan.

SIR,—By inserting the following mathematical questions in an early number of the "Artisan," you will greatly oblige your's, &c. J. M. EDNEY.

3, *St. John's-street, Clerkenwell.*

1st. The diameter of a circle is 30 feet; required the side of a regular heptagan of equal area?

2d. What number is that which consists of two digits, to which if 54 be added, there arises a number having the same digits inverted; and if from the square of the second digit there be taken the square of the first, the remainder will be 60?

We have inserted the above questions at the request of our Correspondent; but we wish to confine this department of our publication to questions relating to natural philosophy rather than to *pure* mathematics.—EDIT.

To the Editor of the Artisan.

SIR.—Having seen some of the numbers of your valuable publication, which I perceive is wholly devoted to the arts and sciences, I have resolved to take it in regularly, for the use of my pupils, as I conceive it will be the means of inducing them to study the subjects which it contains with more pleasure and attention than by large voluminous works on the same subjects.

In the mean time I will thank you to insert the following experiments in the miscellaneous part of your next number, which will very much oblige your obedient servant,

LUDIMAGISTER.

Belfast, March 22, 1814.

EXPERIMENT 1.—*To exhibit the pressure of the air on liquids.*

Procure a tin vessel, about six inches high and three inches in diameter, with a mouth not quite a quarter of an inch wide; in the bottom make a number of small holes, about the size of the point of a common sewing needle. Plunge the vessel in water, with its mouth open, and when it is full, cork it tight, and take it out of the water. As long as the vessel remains corked, no water will issue from the holes in the bottom; but as soon as it is uncorked, the water will begin to flow from every one of the holes in the bottom. If these holes exceed the tenth part of an inch in diameter, or if they be too numerous, the water will issue from them, though the vessel be corked, because the pressure of the air on the bottom of the vessel will not be sufficient to confine the water.

EXPERIMENT 2.—*To convert a drop of water into a microscope.*

Take a long thin piece of brass, and make a small hole in it, about the twenty-fourth part of an inch in diameter; then holding it by one end, take up a drop of water upon a pin, and lay it on the hole, the water will remain on the aperture in the form of a hemisphere, or plano-convex lens. Or a double convex lens may be made by thrusting the pin through the hole till the water enters it, and then drawing the pin perpendicularly through the hole. When an object is to be viewed by this microscope, take it up upon a pin, or piece of glass, and holding the brass by the end, move the object till it be in the focus, and it will then be seen as distinctly as by a single glass microscope, especially by candle light.

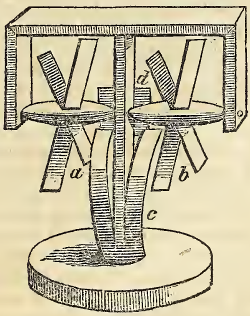
EXPERIMENT 3.—*To produce a change of colour in the sun's rays.*

Hold a white card perpendicularly against the solar rays collected in the focus of a lens, it will exhibit on its back surface a circle of a bright yellow colour; and if turned more and more obliquely, this circle will change to an oval figure, the colour will progressively deepen into an orange, and at last into a dull red.

PNEUMATICS.

TO SHOW THE RESISTANCE OF THE AIR.

13. The following figure represents a small machine, consisting of two mills, *a* and *b*,



which are of equal weights, and turn on their axes with equal forces. Each mill has four thin arms or sails fixed into the axis; those of the mill *a* have their planes at right angles to its axis, and those of *b* have their planes parallel to it. Therefore as the mill *a* turns round in common air, it is but little resisted thereby, because its sails cut the air with their thin edges; but the mill *b* is considerably resisted, because the broad sides of its sails move against the air when it turns round. In each axle is a pin near the middle of the frame, which goes quite through the axle, and stands out a little on each side of it: upon these pins the slider *d* may be made to bear, and so hinder the mills from going, when the strong spring *c* is pressed against the opposite ends of the pins.

Having set this machine upon the pump-plate L L, draw up the slider *d* to the pins on one side, and set the spring *c* to bend upon the opposite ends of the pins; then push down the slider *d*, and the spring acting equally strong upon each mill, will set them both a-going with equal forces and velocities: but the mill *a* will run much longer than the mill *b*, because the air makes much less resistance against the edges of its sails, than against the sides of the sails of *b*.

Draw up the slider again, and set the spring upon the pins as before, then cover the machine with the receiver M, upon the pump-plate (see air pump), and having exhausted the receiver of air, push down the wire P P, (through the collar of leathers in the neck *q*) upon the slider, which will disengage it from the pins, and allow the mills to turn round by the impulse of the spring. And as there is no air in the receiver to make any sensible resistance against them, they will both move a considerable time longer than they did in the open air; and the moment that one stops, the other will do so too. This shows that air resists bodies in motion, and that equal bodies meet with different degrees of resistance, according as they present greater or less surfaces to the air, in the planes of their motions.

14. Take off the receiver M, and the mills employed in last experiment; and, having put a guinea *a*, and feather *b*, upon the brass flap *c*, turn up the flap, and shut it into the notch *d*. Then, putting a wet leather over the top of the tall receiver A B, open at both ends,

cover it with the plate C, from which the guinea and feather tongs *e d*, will then hang within the receiver. This done, pump the air out of the receiver, and then draw up the wire *f* a little, which by a square piece on its lower end will open the tongs *e d*; and the flap falling down as at *c*, the guinea and feather will decend with equal velocities in the receiver, and both will fall upon the pump-plate at the same instant.

In this experiment the spectators ought not to look at the top, but at the bottom of the receiver, in order to see the guinea and feather fall upon the plate; for their descent is so quick, that it is impossible for the eye to observe the beginning and end of their motion.

The foregoing experiments being quite sufficient to prove, that the air is a real substance, possessed of *weight*, and capable of resisting bodies in motion, we shall now give directions for performing a set of experiments to show the elasticity of the air.

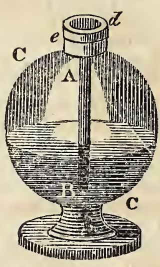
To show the Elasticity or Spring of the Air.

15. Tie up a very small quantity of air in a bladder, and put it under a receiver, then exhaust the air out of the receiver, and the small quantity which is confined in the bladder (having nothing to act against it) will expand itself so by the force of its spring, as to fill the bladder as full as it could be blown of common air. But, upon letting the air into the receiver again, it will overpower the air in the bladder, and press its sides almost close together.

16. If the bladder so tied up be put into a wooden box, and have 20 or 30 pounds weight of lead put upon it in the box, and the box be covered with a close receiver, upon exhausting the air out of the receiver, the air which is confined in the bladder will expand itself so, as to raise the lead by the force of its spring or elasticity.

17. Take the glass ball mentioned in the fifth experiment, which was left full of water, except a small part at top, containing a bubble of air, and having set it with its neck downward into a phial containing a little water, and having covered it with a close receiver, exhaust the air out of the receiver, and the small bubble of air in the top of the ball will expand itself, so as to force all the water out of the ball into the phial.

18, Screw the pipe A B into the pump-plate, place the tall receiver G H upon the plate *c d*, as in the eleventh experiment, and exhaust the air out of the receiver; then turn the cock *e*, to keep out the air, unscrew the pipe from the pump, and screw it into the mouth of the copper vessel C C,

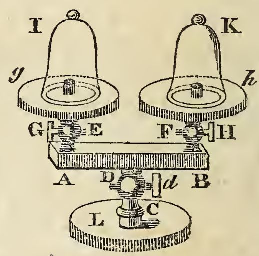


it having first been half filled with water; then open the cock *e* (see fig. experiment 11) and the spring of the air, which is confined in the copper vessel, will force the water up through the pipe AB in a jet into the exhausted receiver, as strongly as it did by its pressure on the surface of the water in a basin, in the eleventh experiment.

19. If a fowl, a cat, a rat, mouse, or bird, be put under a receiver, and the air be exhausted, the animal will be at first oppressed as with a great weight, then grow convulsed, and, at last, expire in all the agonies of a most bitter and cruel death. But as this experiment is too shocking to every spectator who has the least degree of humanity, a machine called the *lungs'-glass*, is generally substituted instead of an animal.

20. If a butterfly be suspended in a receiver by a fine thread, tied to one of its horns, it will fly about in the receiver, as long as the receiver continues full of air; but if the air be exhausted, though the animal will not die, and will continue to flutter its wings, it cannot remove itself from the place where it hangs in the middle of the receiver, until the air be let in again, and then the animal will fly about as before.

21. Screw the end C of the pipe C D into the hole of the pump-plate,



and turn all the three cocks *d*, G, and H, so as to open the communications between all the three pipes E, F, D C, and the hollow trunk A B. Then, cover the plates *g* and *h* with wet leathers, which have holes in their middle, where the pipes open into the plates; and place the close receiver I upon the plate *g*. This done, shut the pipe F, by turning the cock H, and exhaust the air out of the receiver I; then turn the cock *d*, to shut out the air, unscrew the machine from the pump, and having screwed it to the wooden foot L, put the receiver K upon the plate *h*: this receiver will continue loose on the plate as long as it keeps full of air, which it will do until the cock H be turned to open the communication between the pipes F and E, through the trunk A B; and then the air in the receiver K, having nothing to act against its spring, will run from K into I, until it be so divided between these receivers, as to be of equal density in both; and then they will be held down with equal forces to their respective plates, by the pressure of the atmosphere; though each receiver will then be kept down with only one half the former pressure which it had, when it was exhausted of air, because it has now one half of the common air in it, which filled the receiver K, when it was set upon the plate; and therefore, a force equal to half the force of the spring of common air, will act within the receiver against the whole pressure of the common air upon their outsides. This is called transferring the air out of one vessel into another.

22. Put a cork into the square phial A, (see experiment the twelfth) and fix it in with wax or cement: put the phial upon the pump-plate, with the wire cage B over it, and cover the cage with a close receiver; then exhaust the air out of the receiver, and the air that was corked up in the phial will break the phial outwards by the force of its spring, because there is no air left on the outside of the phial to act against the air within it.

23. Put a shrivelled apple under a close receiver, and exhaust the air, then the spring of the air within the apple will plump it out, so as to cause all the wrinkles to disappear; but upon letting the air into the receiver again, to press upon the apple, it will instantly return to its former decayed and shrivelled state.

24. Take a fresh egg, and cut off a little of the shell and film from its smallest end, then put the egg under a receiver, and pump out the air; upon which, all the contents in the egg will be forced out into the receiver, by the expansion of a small bubble of air contained in the great end, between the shell and film.

25. Put some warm beer in a glass, and having set it on the pump, cover it with a close receiver, and then exhaust the air. Whilst this is doing, and thereby the pressure more and more taken off from the beer in the glass, the air therein will expand itself, and rise up in innumerable bubbles to the surface of the beer, and from thence it will be taken away with the other air in the receiver. When the receiver is nearly exhausted, the air in the beer, which could not disentangle itself quick enough to get off with the rest, will now expand itself so, as to cause the beer to be covered with froth, and at last to run over the side of the glass.

26. Put some warm water into a glass, and a small bit of dry wainscot or other wood into the water: then, cover the glass with a close receiver, and exhaust the air; upon which, the air in the wood, having liberty to expand itself, will come out plentifully, and make all the water to bubble about the wood, especially about the ends where the pores are greatest and most numerous. A cubic inch of dry wainscot has so much air in it, that it will continue bubbling for nearly half an hour.

Miscellaneous Experiments.

27. Let a large piece of cork be suspended by a thread at one end of a balance, and counterpoised by a leaden weight, suspended in the same manner at the other. Let this balance be hung to the inside of the top of a large receiver, which, being set on the pump, and the air exhausted, the cork will preponderate, and shew itself to be heavier than the lead; but, upon letting in the air again, the equilibrium will be restored. The reason of this is, that since the air is a fluid, and all bodies lose as much of their absolute weight in it, as is equal to the weight of their bulk of the fluid (see page 9, col. 2.) the cork being the larger body, loses more of its real weight than the lead does; and therefore must in fact be heavier, to balance it under the disadvantage of losing some of its weight; which disadvantage being taken off by removing the air, the bodies then gravitate according to their real quantities of matter, and the cork, which balanced the lead in air, shews itself to be heavier when in *vacuo*.

28. Set a lighted candle upon the pump, and cover it with a tall receiver. If the receiver holds a gallon, the candle will burn a minute; and then, after having gradually decayed from the first instant, it will go out; which shows that a constant supply of fresh air is necessary to feed flame: and also to support animal life. For a bird kept under a close receiver will soon die, although no air be pumped out; and it is found that, in the diving bell, a gallon of air is only sufficient to support a man for one minute.

29. As soon as the candle goes out, in this experiment, the smoke will be seen to ascend to the top of the receiver, and there form a sort of cloud; but upon exhausting the air, the smoke will fall down to the bottom of the receiver, and leave it as clear at the top as it was before it was set upon the pump. This shows, that *smoke* does not ascend on account of its being positively light, but because it is lighter than *air;* and its falling to the bottom of the receiver when the air was taken away, shows that it is not altogether destitute of weight. In a similar manner, different sorts of wood ascend or swim in water: and yet no one doubts that every kind of wood has weight.

30. Set a bell upon a cushion on the pump-plate, and cover it with a receiver; then shake the pump, to make the clapper

strike against the sides of the bell, and the sound will be very well heard; but, exhaust the receiver of air, and then, if the clapper be made to strike ever so hard against the sides of the bell, it will produce no sound at all; which shows, that air is absolutely necessary for the propagation of sound.

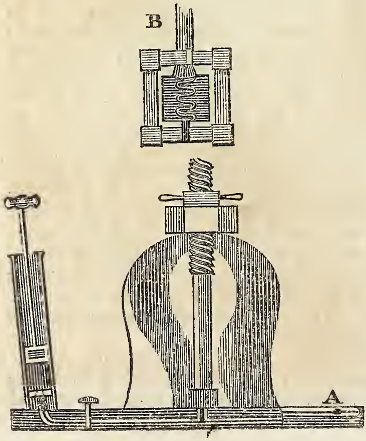
The elastic air which is contained in many bodies, and kept in them by the weight of the atmosphere, may be got out of them, either by boiling, or by the air-pump, as shown in the 26th experiment: but the fixed air, which is by much the greater quantity, cannot be got out but by distillation, fermentation, or some *chemical* process.

If fixed air did not come out of bodies with difficulty, and spend some time in extricating itself from them, it would tear them to pieces. Trees would be rent by the change of air, from a fixed to an elastic state, and animals would be burst in pieces by the explosion of air in their food.

Dr. Hales found, by experiment, that the air in apples is so condensed, that if it were let out into the common air, it would fill a space 48 times as great as the bulk of the apples themselves.

To the foregoing experiments of rarifying the air, or producing a vacuum, we shall add a few observations respecting the condensation of air. When any vessel is employed for the purpose of condensing the air, it ought to be sufficiently strong to bear the force, or resist the increased elasticity which is thus given to it; vessels for this purpose are therefore generally made of brass. If glass be used for a condenser, it will not admit of so great a degree of condensation; but any experiment which may be performed with it will be more pleasant than with a brass vessel, as the experiment may be viewed in all its stages.

The following figure represents a condenser, with screws for confining the receiver.



A is a gage for showing the degree of condensation, B the piston of the syringe, with a valve of the best kind, which is conical, and is confined by a spiral spring. But in common the valves are made of leather, with a plate of metal to strengthen it.

The spring or elasticity of the air will be greater in proportion to its condensation, and, therefore, the sound of a bell will be twice as loud as in the common air, if the air be made twice as dense by injection. A round phial may be broken by condensed air, which could not be broken by the pressure of the common air; and though animals soon die, by not having a requisite quantity of air, yet they will not be easily killed by having that quantity increased by condensation. If air be condensed upon water in a bottle, it will cause it to spout through the tube of communication to a very great height: viz. to 30 feet, if only one atmosphere be injected; to 60 feet, if two atmospheres be injected; and so on.

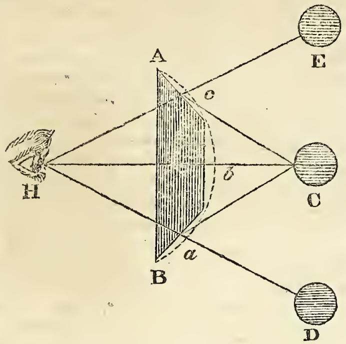
A bladder that will sustain the spring of common air, will be broken by the spring of condensed air. In short, the force of condensed air may be so far increased as to counteract or balance the greatest power which human art can apply. When air is considerably condensed on the surface of water, a greater quantity of caloric or heat is necessary to convert the water into vapour, than when it is pressed only by air of the common degree of density; hence water will boil or go into vapour at a lower temperature, on the top of a high mountain, than at the bottom of it, (see page 33.)

The heat which may be communicated to water by means of pressure, or inclosing it in strong vessels, may be so great as to melt soft *solder*, and even *lead.*

It is by this vast power of heated water and steam, that Papin's Digester effects the dissolution of bones, and reduces them to a jelly, so as to become wholesome and savoury diet; for which purpose they are put into a metalline vessel, with a cover, which is strongly screwed down, and made perfectly air-tight. The Digester being nearly filled with water and bones, is set over a gentle fire, which by degrees converts the water into steam, and which, with the included air, in a short space of time acts upon the bones with so great an energy, as to effect their entire dissolution, and cause them to mix and incorporate so intimately with the water, or broth, as to make a perfect *coagulum*, or jelly, when all is cold, which may be then sliced out with a knife.

OPTICS.

THE *multiplying* glass is made by grinding down the round side of a convex glass A B,



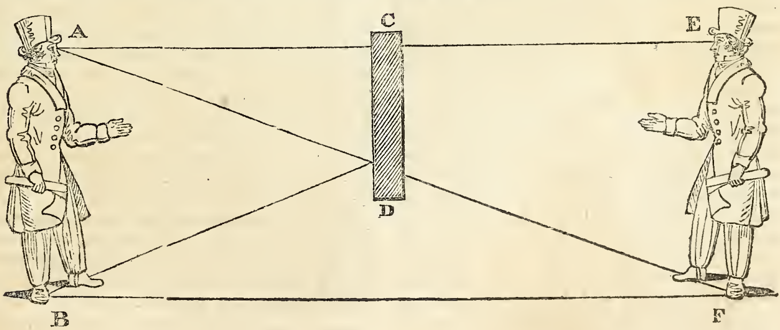
into several flat surfaces. An object C will not appear magnified, when seen through this glass by the eye at H; but it will appear multiplied into as many different objects as the glass contains plane surfaces. For, since rays will flow from the object C to all parts of the glass, and each plane surface will refract those rays to the eye, the same object will appear to the eye in the direction which the rays enter it through the surface. Thus, a ray from the object C, falling perpendicularly on the middle surface *b*, will go through the glass to the eye without suffering any refraction; and will therefore show the object in its true place at C: whilst a ray flowing from the same object, and falling obliquely on the plane surface *c*, will be so refracted by passing through the glass, as to cause the same object C to appear at E, in the direction of the ray H E. And the ray flowing from the object C, and falling obliquely on the plane surface *a*, will be so refracted (by passing through the glass) as to cause the same object to appear at D, in the direction H D.

Though a *plane mirror*, or common looking glass, appears to have no other use than to reflect such images as are placed before it, yet we shall here introduce it for the purpose of stating some of its properties which are not generally known.

When any object is placed before a plane mirror, its image appears as large to the eye as the object itself; and is erect, distinct, and seemingly as far behind the mirror as the object is before it; and that part of the mirror which reflects the image of the object to the eye (the eye being supposed equally distant from the glass with the object) is just half as long and half as broad as the object itself.

Hence it appears, that if a man sees his whole image in a plane looking-glass, the part of the glass that reflects his image must be just *half* as long and *half* as broad as *himself*, let him stand at any distance from it whatever, and that his image must appear just as far behind the glass as he is before it. Thus the man A B, viewing himself in the plane mirror C D, which is just half as long as himself, sees his whole image, as at E F, behind the glass, exactly equal to his own size.

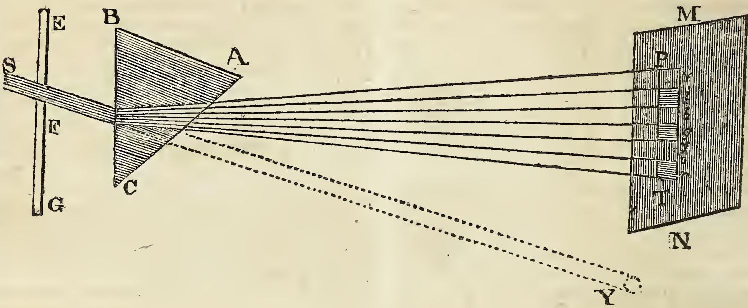
For a ray, A C, proceeding from his eye at A, and falling perpendicularly upon the surface of the glass at C, is reflected back to his eye in the same line CA; and the eye of his image will appear at E in the same line produced to E, beyond the glass.



And the ray, B D, flowing from his foot, and falling obliquely on the glass at D, will be reflected as obliquely, or, in the direction D A; and the foot of his image will appear at F, in the direction of the reflected ray A D, produced to F, where it is cut by the right line B F, drawn parallel to the right line A E.

In all our preceding observations on light we have considered it as a simple substance, and supposed that all its parts or rays had the same properties, and were equally acted upon by the bodies which refracted and reflected them. This, however, though believed to be the case till the time of Sir Isaac Newton, has been completely disproved by his fine experiments with the *prism;* we shall, therefore, now state the means which were employed by that celebrated philosopher to prove that light is a compound substance, capable of being decomposed into its elements, and exhibiting in its elementary state new properties of the most interesting kind. That the light of the sun consists of rays which differ in *colour* and *refrangibility*, may be proved as follows.

In a dark room make a small hole F,



in the window shutter, about one-third of an inch broad; place a glass *prism* ABC in the beam of rays S F, in such a manner that the rays may fall obliquely on one side of the prism, as at A C; the beam of rays which thus fall on the prism will be refracted in different degrees, and will form a series of the most beautiful and lively colours, P T, on the opposite wall, or on a sheet of white paper, MN, held up for the purpose. The image which is thus formed is called the solar *spectrum*, and when most distinctly formed is of an oblong figure, exactly like the shadow of a cylinder.

The colours of the spectrum are *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*, with all their intermediate shades, blended in the softest and most agreeable manner.

Hence the light of the sun consists of a mixture of several sorts of coloured rays, some of which at equal incidences are more refracted than others, and therefore are called *more refrangible*. The red at T, being nearest to the place Y, where the rays of the sun would go directly, if the prism was taken away, is the least refracted of all the rays; and the *orange*, *yellow*, *green*, *blue*, *indigo* and *violet*, are continually more and more refracted, as they are more and more diverted from the course of the direct light. For, when the prism is fixed in the posture above-mentioned, so that the place of the image shall be the lowest possible, the figure of the image ought to be round, like the spot at Y, if all the rays that tended to it were equally refracted. Therefore, since it is found that this image is *not round*, but about five times longer than it is broad, it follows, that all the rays are not equally refracted.

It is also found that the above colours do not occupy equal spaces of the spectrum. If the whole spectrum be divided into 360 equal parts, the *red* space will occupy 45; the *orange* 27; the *yellow* 48; the *green*, 60; the *blue*, 60; the *indigo*, 40; and the *violet*, 80, of these parts.

If all the above colours are blended together again, they will produce a pure *white*. This may be proved by removing the paper on which the spectrum was formed, and placing a large convex glass in its place, the different coloured rays will be so refracted in passing through it as to make them unite in a point; and if a white paper be placed at this point to receive them, they will excite the idea of a lively white. But if the paper be placed farther from the glass than this point, the different colours will again appear upon it, in an inverted order, on account of the rays crossing each other after meeting.*

That the colours of the solar spectrum produce a *white*, when blended together, in the proportion in which they appear in the spectrum, may be exhibited in a different manner, as follows:

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* Light, or rays which appear *red*, or rather make objects appear so, may, with more propriety, be called red-making rays, the same may be said of green, &c. For to speak properly, the rays are not *coloured*, there is only a certain power and disposition in them to excite a sensation of this or that colour. This subject will be treated of more fully in another part of our work.

Draw two concentric circles on a smooth board or card, at a little distance from each other, then divide the outer circle in 360 equal parts, or degrees, and mark them off in the proportion stated above; then draw straight lines from the centre of the circles to the different divisions, and paint each of the spaces included between the circles of its respective colour, that is, the space which contains 45 degrees is to be painted red; that which contains 27, orange: and the others as stated above. When this is done, paint the space within the inner circle black, and put a pin through the centre, then turn the card swiftly round on the pin, and the space within the two circles which was painted of different colours will appear like a white ring, inclining to *grayish.*

The white will be more or less brilliant as the colours are skilfully or unskilfully blended at the extremities of each division.

It has been lately discovered by Dr. Wollaston, that if a *small* aperture be viewed through a *prism*, or if the sun's light passing through a small aperture fall upon a prism, the spectrum thus produced contains only *four* colours; it therefore follows, that the *other* colours in the spectrum described by Newton are *compound tints*, and have refrangibilities, the same as other rays in the Newtonian spectrum. The *yellow* rays, for example, in the Newtonian spectrum, have the same refrangibility as some of the *green*, and also some of the *red* rays in the same spectrum, and their apparent existence as separate rays arises entirely from the analysis not being complete, in consequence of too large an aperture having been used.

From these experiments Dr. Wollaston and Dr. Young have concluded, that the *yellow rays have not a separate existence in the spectrum*. Dr. Young, who repeated Dr. Wollaston's experiments with perfect success, remarks that there is a *narrow yellow line*, generally visible at the limit of the *red* and *green*, but that its breadth scarcely exceeds that of the aperture by which the light is admitted, and that Dr. Wollaston attributes it to the *mixture of the red with the green light.*

Dr. Brewster has, however, recently shewn, that the yellow rays have a separate and independent existence in the spectrum, formed in the manner described by Dr. Wollaston, and that they are only mixed with the most refrangible red and the least refrangible green, with which they have the same refrangibility. By the use of coloured *media* which absorb these two kinds of rays, he has been able to insulate the yellow space, so as to establish its existence beyond a doubt.

When a pencil of white light is separated into its component colours, it is said to be *dispersed* by the prism; that is, the extreme *red* and the extreme *violet* rays are dispersed or separted from the middle rays of the spectrum.

Light, whose rays are all alike refrangible, are called *simple, homogeneous*, and *similar*; and that whose rays are not all alike refrangible, are called *compound, heterogeneous* and *dissimilar.*

The colours of homogeneous lights are called *primary, homogeneous* and *simple;* and those of heterogeneous lights, *heterogeneous* and *compound.* For these are always compounded of homogeneous lights.

CHEMISTRY.

Carbon is very fixed, perfectly, infusible, and insoluble in heat, and passes, with justice, for the most refractory body in nature. Thus it is frequently employed as a crucible for containing matters difficult of fusion, or, as a support, when many bodies are treated by the blow-pipe. As carbon is a bad conductor of heat, it is used with success to line crucibles, to coat furnaces, and confine the heat, the infusible property of this body accompanies the property of not conducting caloric. In many of the arts this property becomes of the greatest utility.

When the temperature of charcoal is raised to ignition, and is then placed in contact with oxygen gas, the carbon burns with activity, sparkling, and slightly-brilliant, but very sensible flame. It quickly disappears, becomes fused in the oxygen gas, and consequently assumes the fluid elastic form. It is found, that twenty-eight parts of carbon thus disappears, and unites with seventy-two parts of oxygen gas, and that there results from this combustion a new gas which occupies less space than the oxygen gas, but its specific weight is almost double. This gas received the name of *carbonic acid* as already mentioned, and will be treated of under that head.

What happens when charcoal is burned in a given quantity of common air, or when that air is not renewed, may be now understood. The ignited carbon combines gradually with the oxygen gas of the atmosphere, and becomes dissolved in such a manner as to lose its visible mass, and only to leave a few atoms of its ashes.

The air thus vitiated and really destroyed, as to its vital and respirable parts, by this combustion, produces very fatal accidents. It will be also seen that other circumstances, relative to charcoal, also augment its danger.

Carbon unites with all the simple combustibles, and with azote, or nitrogen; with sulphur it forms a curious limpid liquid called carburet of sulphur, or sulphuret of carbon*; with phosphorus it forms a compound whose properties are but imperfectly ascertained. With azote, it forms cyanogen or prussic acid gas.

There exists so marked an attraction between carbon and hydrogen, that the compound (which is named carbonated hydrogen, or carburetted hydrogen) is frequently met with among vegetable compounds.† But, besides this attraction of the *radicals*, hydrogen gas may easily hold in solution a greater or less quantity of carbon, which happens whenever it is disengaged from a substance which itself contains carbon more or less abundant and divided. This solution is obtained very varied, and in a number of chemical operations, from the simple exposure of charcoal, in a glass full of hydrogenous gas to the rays of the sun. In which exposure the charcoal is seen to dissipate, and the hydrogenous gas to diminish in volume in proportion as it is dissolved.

It is also produced by the rapid decomposition of vegetables by heat, as well as by the spontaneous change which vegetable and animal substances undergo at the bottom of stagnant waters. In all these circumstances, carbonated hydrogen gas is obtained. Charcoal itself, when humid, or when it has been for some time immersed in hydrogen gas, begins, when lighted, to exhale through the atmosphere this deleterious gas, which also augments the danger of its combustion in close places.

Carburetted hydrogen gas, formed so easily in all the conditions here explained, varies according to the proportions of carbon which it contains, and assumes properties varied, also according to these proportions, in such a manner, that it has been regarded and described as if it formed so many different inflammable gases. That which is disengaged from stagnant waters or bogs, from peat, privies, and sinks; that which is obtained from the solution of some carbonated metals during their oxydation in the weak acids; that which frequently exhales from coal pits, from the mouths of volcanos; those gases which are derived from vegetable and animal matters distilled at different temperatures, from alcohol, from ether, from oils, treated by different re-agents, particularly by the concentrated acids;—all these different inflammable gases, are carburetted hydrogen gas, forming as many varieties as there are different proportions of their principles; and sometimes also other combustible matters are added to the carbon, dissolved in hydrogen gas, which always forms its base or radical.

However numerous the varieties of carburetted hydrogen gas may thus appear, as well as the properties which it presents, there may however, be discovered in the whole of these varieties, a series of characters which connect them, and which constitute them a distinct genus of compounds. It is very evident, that we must here attend only to the *generic*, or general characters. Carburetted hydrogen gas is heavier than pure hydrogen gas; and can but seldom be used for inflating aerostatic machines; it has a fetid odour which is so much the stronger, as it holds more of carbon in solution; it extinguishes inflamed combustible bodies, and more completely stupifies animals than pure hydrogen gas; it, in general, burns with less rapidity than this last: its flame is often blue and pale, sometimes it is red or white, very brilliant, and, as it were, oily. It frequently deposits carbon, distinguishable by its black colour, when treated by different processes; it is, in general, more easily and more abundantly condensed, or absorbed, by charcoal. In some circumstances, it forms oil, and it has then been particularly named olefiant gas, which will be treated of in another part of this work.

The uses of carbon are very numerous in chemistry; its strong affinity for oxygen is employed with great success. After hydrogen, this substance attracts it more strongly than any other body; and, at high temperatures, it even attracts oxygen more strongly than hydrogen itself: it is, for this reason, that we have placed it immediately after hydrogen.

It will afterwards be shown, that carbon is particularly used, to abstract oxygen from many burned bodies, to reduce them to their simple state of combustibility. It is no longer doubtful, that carbon is a principle employed by Nature, in forming the greatest number of her compounds: it it will be shown hereafter, that it constitutes the base of all vegetable substances, and, that it performs a very important part in the great work of animal economy.

A singular and important property of charcoal is that of destroying the smell, colour, and taste of various substances:

* When the simple combustibles, carbon, sulphur, or phosphorus, combines with any substance, the compound is called a carburet, sulphuret, or phosphuret, according as one or other of these bodies enters into combination with the substance. If any of these bodies combine with each other, the compound is denoted by placing the name of that substance first which predominates in the compound. Thus, if phosphorus and sulphur are combined in such a proportion, that the phosphorus predominates, it would be called phosphuret of sulphur.

† This gas is called carburetted hydrogen by some chemists, and carbonated by others, we shall generally use the first of these terms.

for the first accurate experiment on which we are chiefly indebted to Mr. Lowitz, of Petersburgh, though it had been long before recommended to correct the fœtor of foul ulcers, and as an antiseptic. Water, that has become putrid by long keeping in wooden casks, is rendered sweet by filtering through charcoal powder, or by agitation with it; particularly if a few drops of sulphuric acid be added. Common vinegar boiled with charcoal powder becomes perfectly limpid. Saline solutions, that are tinged yellow or brown, are rendered colourless in the same way, so as to afford perfectly white crystals. Malt spirit is freed from its disagreeable flavour by distilation with charcoal; but if too much be used, part of the spirit is decomposed. Simple maceration, for eight or ten days, in the proportion of about 1-150th of the weight of the spirit, improves the flavour much. It is necessary, that the charcoal be well burned, brought to a red heat before it is used, and used as soon as possible, or at least be carefully excluded from the air. The proper proportion too should be ascertained by experiment on a small scale. The charcoal may be used repeatedly, by exposing it for some time to a red heat before it is again employed.

Charcoal is used on particular occasions as *fuel*, on account of its giving a strong and steady heat without smoke. It is employed to convert iron into *steel* by cementation. It enters into the composition of gunpowder. In its finer states, as in ivory black, lamp black, &c. it forms the basis of black paints, Indian ink, and printers' ink.

It has already been remarked, that the *Diamond* is carbon nearly *pure*. This was verified in 1694 by the Florentine academicians, in the presence of Cosmo III. Grand Duke of Tuscany. By means of a burning-glass they consumed several diamonds.* Francis I. Emperor of Germany, afterwards witnessed the destruction of several more in the heat of a furnace. These experiments were repeated by Darcet, Rouelle, Macquer, Cadet, and Lavoisier; who proved, that the diamond was not merely evaporated, but actually burnt, and, that if air was excluded it underwent no change.

Mr. Lavoisier prosecuted these experiments with his usual precision; burnt diamonds in close vessels by means of powerful burning-glasses; ascertained, that during their combustion carbonic acid gas was formed; and, that in this respect there was a striking analogy between them and charcoal, as well as in the affinity of both when heated in close vessels. A very high temperature is not necessary for the combustion of the diamond. Sir George Mackenzie ascertained, that they burn in a muffle† when heated to the temperature of 14° of Wedgewood's pyrometer; a heat considerably less than is necessary to melt silver. When raised to this temperature they waste pretty fast, burning with a low flame and increasing somewhat in bulk; their surface too is often covered with a crust of charcoal, especially when they are consumed in close vessels by means of burning glasses.

The experiments of Lavoisier have often been repeated by several chemists, particularly by Morveau, and Tennant; and from the result of their experiments it is demonstrated, that the diamond affords no other substance by its combustion than pure carbonic acid gas; and, that the process is merely a solution of diamond in oxygen gas, without much change in the volume of the gas.

The only chemical difference *perceptible* between diamond and the purest charcoal is, that the charcoal contains a minute portion of hydrogen; it, therefore, becomes an important question to determine if this very minute portion of hydrogen can occasion so great a *physical* difference as exists between these substances. This is a question, however, that remains to be determined.

OF PHOSPHORUS.

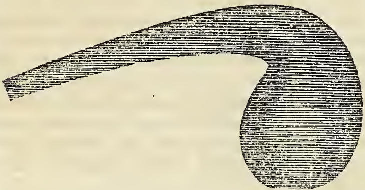
Phosphorus, the third of the simple combustibles, when placed in the order of its affinity for oxygen, may be procured by the following process: put a quantity of bones into a crucible and burn or *calcine* them, till they cease to smoke, or to give out any odour, and afterwards reduce them to a fine powder. Put 100 parts of this powder into a basin of porcelain or stoneware, dilute it with four times its weight of water, and then add gradually (stirring the mixture after every addition) 40 parts of sulphuric acid. The mixture will become hot, and a vast number of air-bubbles will then be extricated. Leave the mixture in this state for 24 hours; taking care to stir it well every now and then with a glass or porcelain rod to enable the acid to act upon the powder.

The whole is now to be poured on a filter of cloth; the liquid which runs through the filter is to be received in a porcelain basin; and the white powder which remains on the filter, after pure water has been poured on it repeatedly, and allowed to strain into the porcelain basin below, being of no use, may be thrown away.

* Though the diamond, was till this period considered to be incombustible, yet Sir I. Newton suspected, that it was combustible, from the great power it has of refracting the rays of light.

† A *muffle* is a kind of small earthen-ware oven, open at one end, and fitted into a furnace.

Into the liquid contained in the porcelain basin, which has a very acid taste, pour nitrate of lead,* dissolved in water very slowly; a white powder will immediately fall to the bottom: the nitrate of lead must, however, be added as long as any of this powder continues to be formed, and when this ceases to be the case, throw the whole upon a filter. The white powder which remains upon the filter is then to be well washed, allowed to dry, and afterward mixed with about one-sixth of its weight of charcoal powder. This mixture is to be put into an earthen ware retort; and then put into a furnace, and the



beak of it plunged into a vessel of water, so as to be just under the surface. Heat is now to be applied gradually till the retort be heated to whiteness. A vast number of air bubbles issue from the beak of the retort, some of which take fire when they come to the surface of the water. At last there drops out a substance which has the appearance of melted wax, and which congeals under the water. This substance is *phosphorus.*

An alchemist of Hamburgh, named Brandt, who, in searching for the philosopher's stone which he did not *find*, was the first who, by chance, in 1677, discovered this phosphorus for which he did not *seek.* The singularity of this new product induced Kunckel to associate with one of his friends, named Kraft, to purchase the secret of its preparation: but Kraft having deceived his friend by procuring the secret for himself, of which Kunckel knew nothing more than that the phosphorus was prepared from urine, this philosopher had the courage to undertake the work of discovery. He, at last, succeeded in obtaining phosphorus, which was long called the phosphorus of Kunckel, on account of the success of his enlightened researches. Boyle passes also for having discovered phosphorus, and having deposited the process with the secretary of the Royal Society of London, in 1680. In 1679, Kraft brought a small piece of it to London to show it to the King and Queen of England. Boyle gave his process to Godfrey Hankwitz, a practical chemist of London, who, for many years, sold the product to all the philosophers of Europe. This last operator, and Kunckel, were, for some time, the only chemists who knew how to prepare it. Boyle, however, described his process in the philosophical transactions for 1680; and Kraft inserted his method in a treatise on phosphorus by the Abbe de Commines published in June, 1683, though he had several times sold it before.

That of Brandt was communicated in Hooke's Philosophical Collections, published in English, in 1726, by Derham. Homberg published a process, which he said he had seen practised by Kunckel, in the Memoirs of the Academy of Sciences for 1692.

Phosphorus was, however, made but seldom, with difficulty, and in small quantities in the laboratories, and it was a mere object of curiosity, and the subject of a few philosophical experiments. A small stick or two of phosphorus usually composed the whole portion in cabinets, when in 1774, Gahn and Scheele in Sweden made a capital discovery, which greatly augmented the quantity of phosphorus produced in the laboratories, by showing, that the acid from which it was extracted is abundantly contained in the bones of animals; but, notwithstanding all these researches, it is still the scarcest, the most expensive, and consequently the least employed of simple combustible bodies.

* This substance is procured by dissolving lead in nitric acid or *aquafortis;* but it, as well as the other substances which may be mentioned in the course of this part of our work, will be fully described under their proper head, or class to which they belong.

ASTRONOMY.

Respecting the Light of the sun, little was known till the time of Sir Isaac Newton. Before his time, light had always been esteemed a mere quality or modification of matter; but it is now generally believed to be a *real substance,* or distinct species of matter, emanating or flowing from some luminous body, although in exceedingly small particles. It is also known that these particles proceed from the luminous body in straight lines; but their velocity exceeds every species of motion with which we are acquainted.

The velocity of light is to the velocity of the earth in her orbit as 10,300 to 1, although she moves at the rate of 68,000 miles per hour; therefore light flies at the rate of 187,878 miles per second, which is about 1,550,000 times faster than a cannon ball. This prodigious velocity of the particles of light, if they were not exceedingly small, would prove fatal to our eye sight; for they would strike with such force, that our eyes could not bear the shock.

The time which light takes to arrive at the earth from the sun is 8′ 13″. This was discovered by Roemer, a Danish astronomer, in the year 1644: By comparing the eclipses of the first satellite of Jupiter with the times of its immersions and emersions, given by the tables of Cassini, he found that the error of the tables depended on the distance between Jupiter and the earth; and hence he concluded that the motion of light was not instantaneous, and that it moved through the diameter of the earth's orbit in about 11 minutes. This, though a sufficient discovery or proof of the progressive motion of light, was not accurate enough to determine its true rate of velocity. However, this was soon after discovered by Dr. Bradley, to be what it is stated at above. The intensity of light and heat varies as the square of the distance. For if an object be placed one foot distant from a candle, and another two feet, the one that is two feet distant will only receive one fourth part of the light that the other does; and if it be removed to the distance of three feet, it will only receive one ninth part, and so on. It is the same with respect to the heat imparted by any body.

OF THE PLANET MERCURY.

Mercury is the nearest planet to the Sun, and performs his revolution round that luminary in the shortest period of all the planets. The time he takes to perform this revolution is 87d. 23h. 14′ 32.7″*, which is the length of his year. The length of his day, or the time he takes to perform a revolution round his axis, is not known: for, by reason of his proximity to the Sun, few observations can be made upon him. He is so near the Sun, that he can seldom be seen; and when he does make his appearance, his motion is so rapid towards the Sun, that he can only be discerned for a very short time. When he can be seen, it is a little before the Sun rises in the morning, and a little after he is set in the evening. His distance from the Sun is 36,668,373 English miles, and his diameter is 3,241 miles, which makes him about $\frac{1}{15}$ part of the size of the Earth. The rate at which he moves in his orbit is not known. The light and heat he receives from the Sun are seven times greater than the Earth, and the sun appears seven times as large to him as to the Earth.

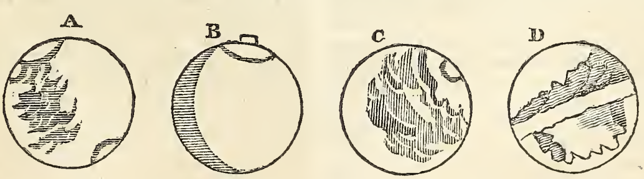
This planet appears to us with all the various phases of the Moon, when viewed at different times with a good telescope; but he never appears quite full, because his enlightened side is never turned directly towards the Earth, except when he is so near the Sun as to be lost to our sight in his beams. His enlighted side being thus always turned towards the Sun, proves that he shines not by any light of his own; for if he did, he would always appear round and fully enlightened. It is also plain he moves in an orbit within that of the Earth's, because he is never seen opposite to the Sun, nor above 56 times the Sun's breadth from him, his greatest Elongation being about 28°. In heathen mythology, Mercury is styled the Messenger of the Gods.

OF VENUS.

Venus is the next planet in order, and computed to be 68,518,044 English miles distant from the Sun. She moves at the rate of 76,000 miles per hour; and completes her revolution round the Sun in 224 days, 16 hours, 41 minutes, and 28 seconds.

The time she takes to revolve round her axis, or the length of her day, is by some astronomers stated at 23h. 21′, and by others at 24d. 8h. Venus is much about the size of our earth, her diameter being 7687 English miles. When examined by a good telescope, she exhibits the same phases as Mercury and the Moon; and her surface is occasionally variegated by darkish spots. These spots were employed by Cassini and Bianchini in determining the revolution of Venus about her axis.

In the following figure A represents Venus, according to the late Sir William Herschel, and B C according to Shroeter.



Venus is never seen opposite to the Sun, nor more than 96 times the breadth of that luminary from his centre, her greatest elongation being about 47°, which proves that her orbit includes that of Mercury. When Venus is to the west of the Sun, she is to be seen before the Sun rises, and is then called the Morning Star; when she is

* The time which any planet takes to perform its revolution round the sun, is called the length of its year; and the time which it takes to revolve round its axis, the length of its day.

east of the Sun, she is to be seen after he sets, and is then called the Evening Star. Venus is in each of these situations for 290 days together. This may at first seem surprising, that she should keep longer on the east or west side of the Sun than the whole time of her revolution round him. But when it is recollected, that the Earth is all the while going round the Sun the same way, though not so quick as Venus, the difficulty vanishes. For the relative motion of Venus to the Earth must, in every period, be as much slower than her absolute motion in her orbit, as the Earth during that time advances forward in the ecliptic, which is 220 degrees. To us Venus appears brightest when her elongation is about 40 degrees, both before and after her inferior conjunction.

Some astronomers have imagined that they perceived a satellite near Venus; but this has since been proved to have been an illusion; for, in her transit over the Sun's disc, she appeared unaccompanied by any satellite.* Mr. Ferguson thinks Venus may have a satellite revolving round her, though it has not yet been discovered; and adds, "that this will not appear very surprising, if we consider how inconveniently we are placed for seeing it."

OF THE EARTH.

The Earth performs its revolution round the Sun in an orbit between that of Venus and Mars, at the distance of 95,173,000, in 365 days, 5 hours, 48 minutes, 49 seconds, which is called the solar or tropical year. In performing its annual circuit, the Earth travels at the rate of 68,000 miles every hour, which is 140 times faster than that of a cannon ball. The diameter of the Earth is 7,912 English miles, and its circumference 24,855·42 miles.† That the Earth is round like a globe, is evident from its shadow in Eclipses of the Moon: for, 1st, The shadow is always bounded by a *circular* line, although the Earth be constantly turning its different sides to the Moon. 2d, By people at land only seeing the upper part of the mast of a ship when she first comes in sight, and as she approaches the land the whole of her gradually becoming visible. 2d, By its having been sailed round by many navigators.

Several degrees of a meridian circle on the Earth's surface have been measured in different parts, by which it has been discovered, that a degree is longer at the poles than at the equator, and therefore the true figure of the Earth is that of an oblate spheroid, the equatorial diameter exceeding that of the polar by 26¾ miles. This deviation from the real spherical shape is occasioned by the diurnal rotation on its axis; for the gravity of the equatorial parts is diminished by the centrifugal force arising from their rapid motion, while the gravity at the poles suffers no diminution.

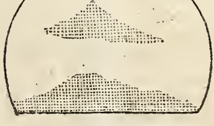
OF MARS.

The planet Mars is 4,142 miles in diameter, and performs his revolution round the Sun in 686 days, 22 hours, 18 minutes, at the distance of 144,588,575 miles. His motion in his orbit is about 55,000 miles per hour. The time he takes to revolve round his axis is 24 h. 39′ of our time. The quantity of light and heat which Mars enjoys is only equal to half what the Earth enjoys; and the Sun only appears to him half as large as to the Earth. This planet being only about a fifth part of the size of the Earth, if any satellite attends him, it must be very small, and has not yet been discovered. To Mars the Earth and Moon appear like two moons, a larger and a smaller, changing places with each other, and appearing sometimes horned, and sometimes half or three quarters enlightened, but never full; and never above a fourth part of a degree distant from one another, although they are 240,000 miles asunder. Mars is very remarkable for the red colour of his light, and for the great number and variety of spots which mark his surface.

The following figure A, B, C, and D, represent the different appearances of Mars as seen by the late Sir W. Herschel, through the astronomical telescope; they are therefore inverted.

A

B



C

* A transit of Venus happens very seldom. Only two occurred in the last century; one in 1761, and the other in 1769. There will not be another till the year 1874. Transists of Mercury happen much oftener. There was one of this planet in 1822; but it was not visible in Britain.

† This is what the French mathematicians have lately deduced from a measurement of above 12° of the meridian.

The atmosphere of this planet, which astronomers have long considered as of an extraordinary size and density, is the cause of the singular redness of its light.

When observed by a good telescope, Mars sometimes appears gibbous, or more than half, but never horned; which shows that his orbit includes the Earth's within it, and also that he does not shine by any light of his own.

In heathen mythology, Mars is styled the God of War.

OF JUPITER.

The planet Jupiter is the largest of all the planets, his diameter being 89,170 English miles. The time he takes to perform his revolution round the Sun is 4330 days, 14 hours, 39 minutes; but his motion round his axis is extremely rapid, being completed in the short space of 9 hours, 55 minutes. His distance from the Sun is stated at 492,665,207 English miles; and his hourly motion in his orbit at 25,000 miles.

The form of Jupiter, like that of the Earth, is an oblate spheroid, the equatorial diameter being to the polar at 14 to 13.

When this planet is examined through a good telescope, several belts or bands are perceived extending across his disc, in lines parallel to his equator.

(To be continued.)

Miscellaneous Subjects.

BIOGRAPHICAL MEMOIR OF THOMAS SIMPSON.

(Continued from page 94.)

He proposed, and resolved many questions in the Ladies' Diaries, &c. sometimes under his own name, as in the years 1735 and 1736, and sometimes under feigned or fictitious names; such as, it is thought, Hurlothrumbo, Kubernetes, Patrick O'Cavenah, Marmaduke Hodgson, Anthony Shallow, Esq. and probably several others. See the diaries for the years 1735 to 60. Mr. Simpson was also the editor or compiler of the Diaries from the year 1754 till the year 1760, both inclusive, during which time he raised that work to the greatest degree of respect.

It has also been commonly supposed, that he was the real editor of, or had a principal share in, two other periodical works of a miscellaneous mathematical nature; viz. the Mathematician, and Turner's Mathematical Exercises, 2 volumes in 8vo. which came out in periodical numbers, in the years 1750 and 1751, &c.

In the year 1763, when the plans proposed for erecting a new bridge at Blackfriars were in agitation, Mr. Simpson, among other gentlemen, was consulted upon the best form for the arches, by the New-bridge Committee.

Upon this occasion he gave a preference to the semicircular form; and besides his report to the Committee, some letters also appeared, by himself and others, on the same subject, in the public newspapers.

From Mr. Simpson's writings, we now return to himself. Through the interest and solicitations of the beforementioned William Jones, Esq. he was, in 1743, appointed professor of mathematics, then vacant by the death of Mr. Derham, in the Royal Academy at Woolwich; his warrant bearing date August 25th. And in 1745 he was admitted a fellow of the Royal Society, having been proposed as a candidate by Martin Folkes, Esq. President, William Jones, Esq. Mr. George Graham, and Mr. John Machin, Secretary; all very eminent mathematicians. The president and council, in consideration of his very moderate circumstances, were pleased to excuse his admission fees, and likewise his giving bond for the settled future payments.

At the academy he exerted his faculties to the utmost, in instructing the pupils who were the immediate objects of his duty, as well as others, whom the superior officers of the ordnance permitted to be boarded and lodged in his house. In his manner of teaching he had a peculiar and happy address; a certain dignity and perspicuity, tempered with such a degree of mildness, as engaged both the attention, esteem, and friendship of his scholars; of which the good of the service, as well as of the community, was a necessary consequence.

In the latter stage of his existence, when his life was in danger, exercise and a proper regimen were prescribed him, but to little purpose: for he sunk gradually into such a lowness of spirits, as often in a manner deprived him of his mental faculties, and at last rendered him incapable of performing his duty, or even of reading the letters of his friends; and so trifling an accident as the dropping of a tea-cup would flurry him as much as if a house had tumbled down.

The physicians advised his native air for his recovery: and in February 1761, he set out, with much reluctance (believing he should never return) for Bosworth, along with some relations. The journey fatigued him to such a degree, that upon his arrival he betook himself to his chamber, where he grew continually worse and worse, to the day of his death, which happened the

14th of May, in the fifty-first year of his age.

At his death, Mr. Simpson left in being, besides his widow, her daughter and son by her first husband, and his own daughter and son, the latter of whom was born after his arrival in London. The two daughters had married officers of artillery, and young Simpson had been presented with a commission in the same corps, and lived to have a company in the Royal Artillery; but on account of a besotted habit of drunkenness, and other misconduct, he was broke, and died soon after.

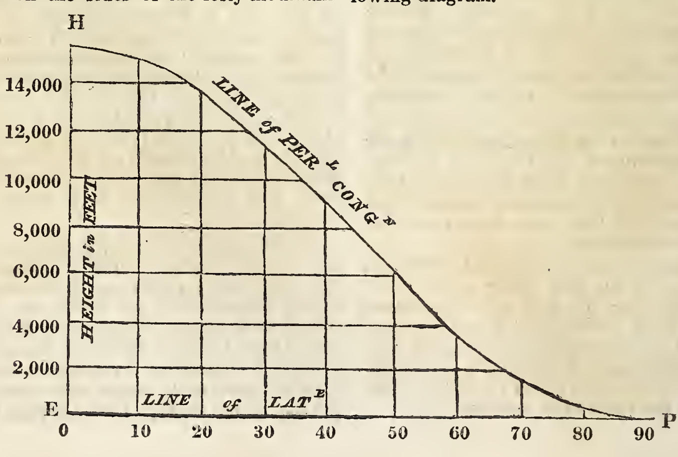
As to Mr. Simpson's widow, the King, at the instance of Lord Viscout Ligonier, the then Master General, in consideration of Mr. Simpson's great merits, was graciously pleased to grant her a handsome pension for life, together with apartments adjoining to the academy; a favour that had never been conferred on any before. Here she lived, and her son Swinfield, the tailor, and his wife, along with her, in the same apartments, for many years. She died only December the 14th, 1782, at the great age of one hundred and two. Her son Swinfield survived her only a few years.

ON THE LINE OF PERPETUAL CONGELATION.

In consequence of the diminution of temperature which is experienced as we ascend in the atmosphere, it is evident that in every climate a point of elevation may be reached where it will be continually freezing. The altitude of the point above the surface of the earth, will depend partly on the temperature of the lower regions of the atmosphere, and partly on the decrement of heat belonging to the column at the period of observation. Thus, near the equator, it was observed by Bouguer, that it began to freeze on the sides of the lofty mountain Pinchencha, at the height of 15,577 feet above the level of the sea, whereas congelation was found by Saussure to take place on the Alps at the height of 13,428 feet. By tracing a line on the plane of the meridian, through the points at which it constantly freezes, a curve is obtained, which has been denominated the line of *Perpetual Congelation.* The height at which this curve intersects a vertical line in the various latitudes, has been computed by Kirwan, partly from observation, and partly from the mean temperature of the parallel, and the decrement of heat, as we ascend in the atmosphere. The following table exhibits the result of his calculation; and though it is constructed on the erroneous supposion, that the mean annual temperature of the pole is 31°, which according to the observations of Captain Scoresby and Captain Parry, must be far beyond the truth, it is tolerably accurate for the more accessible regions of the globe.

Latitude.	Mean Height of Line of Congelation.
.0	15,577
5	15,457
10	15,067
15	15,498
20	13,719
25	13,030
30	11,592
35	10,664
40	9,016
45	7,658
50	6,260
55	4,912
60	3,684
65	2,516
70	1,557
75	748
80	128

These numerical relations will be best perceived at a glance, by means of the following diagram.



Here E P represents the rectified meri-ian from the equator to the pole divided nto intervals of 10° each; and the different erpendiculars or ordinates at the point , 10, 20, &c. represent the height of the *eezing point* at the equator, and at latitude 0, 20, &c. to the pole P. The curve HP, hich has a contrary flexure about 60°, xhibits the general form of the line of 'erpetual Congelation from the equator to e pole.

NEW FRENCH WEIGHTS AND MEASURES.

During the time of the French republic, a new system of weights and measures was introduced into France, the foundation of which was the measure of a degree of the meridian.

This was determined to be 57027 toises, from the mean of the measurement of 12 degrees, about latitude 45 deg.; hence a quadrant of the meridian is 5132430 toises, and from this number the weights and measures now used in France are deduced.

The *Metre*, which is the base of the new system, is the 10,000,000 part of 5132430 toises, or quadrant of the meridian, and is equal to 39·371 English inches. The other measures of length both ascend and descend, decimally, as follows:—

10 Metres	=	1 Decametre.
10 Decametres	=	1 Hectometre.
10 Hectometres	=	1 Kilometre or mile.
10 Kilometres	=	1 Myriametre or league
1 Metre	=	10 Decimetres.
1 Decimetre	=	10 Centimetres.
1 Centimetre	=	10 Millimetres.

The square of the Decametre constitutes the Are, and that of the Hectometre, the Hectare, or Acre.

The cube of a Metre forms the unit of *solid* measure, or the *Stere;* and that of a Decimetre, the Litre, or *Pint;* and the weight of this bulk of water, at its greatest contraction, makes the Kilogramme, or *Pound;* and the weight of the cube of a Centimetre of distilled water is called the Gramme.

The value of these in English measure are as follows:—

The Toise	=	76·7344 English inches.
or 1 Toise	=	1·0657 fathoms.
1 Metre	=	39·371 inches.*
1 Myriametre or league	=	6·213856 English miles.
1 Are	=	1077·119234 square feet.
1 Hectare or Acre .	=	2·47117 English acres.
1 Stere	=	35·3171 solid feet.
1 Litre	=	61·0280 cubic inches.
1 Kilogramme or pound	=	2·1133 troy ounces.
1 Gramme	=	15·444 troy grains.

* 1 Decimetre is = 3.93710 inches.
1 Centimetre = .39371 do.
1 Millimetre = .03937 do.

ANSWER TO QUERIES,

AT PAGE 64.

Not having received any answer to the queries of *Aquatus* and of a *Mechanic*, we shall here give our own opinion on the subject of these queries. And on the *first*, we can only say, that, as far as our experience and observations extend, we know of no exception to the general law of all *dry solid* bodies becoming *hot* by *friction*, or rubbing. But we are not philosophers enough to give any good reason why *liquids* do not become *hot* by the same means. Perhaps it may be on account of the want of *cohesion* between their minute particles, or on account of the *form* of their particles.

On the query of a Mechanic we have to remark, that we know of no instrument which exhibits, by *inspection*, any temperature between seven hundred and a thousand degrees of Fahrenheit's scale. Between the boiling point of mercury (about 660°) and the commencement of Wedgwoods pyrometer (about 1077° of Fahrenheit's) there is no method of ascertaining the temperature of a body but by induction, or inferences drawn from a comparison of the mercurial thermometer with Wedgwood's, or other pyrometers.

Though "V" might have applied to any other person with equal propriety as to us, to solve his queries, (they having no reference to the "Artisan") we shall, on this occasion, comply with his request. The 45th of Euc. b. 1, is perfectly general; and it matters not whether it be illustrated by a *four*, or a forty-sided rectilineal figure; but in no instance could it supersede, or be superseded by, any part of the 32d of the 1st Book. The 32d and its corollories relate entirely to *angles*, whereas the 45th relates to *space*, or *area*.

There is no more connection between the 7th and 8th of Book 3d, than any two propositions in the Elements. The fact is, there is no connection at all between them; and the one is not even alluded to in the proof of the other.

In the 28th of the 3d, there is no necessity either to *assert* or *prove* that *equal* straight lines in the *same* circle cut off equal circumferences; because if this be the case in *equal* circles, it is perfectly evident it must do so in the *same* circle; and the truth is, it could not *be a circle* unless this were the case; *ergo*, "V. is wrong in every thing."—Edit.

SOLUTIONS OF QUESTIONS.

To the Editor of the Artisan.

SIR,

Please insert the following solution of Mr. Graham's question, inserted at page 64 of the Artisan, which will oblige, your's, &c. VULCAN.

The cubical content of the whole globe, including the glass, is $282+1=283$, which divided by 5·236 (the solidity of a sphere whose diameter is 1), and the cube root of the quotient extracted gives 8·146 for the diameter of the globe; and 282, the cubic inches of ale, divided by 5·236, and the cubic root extracted, gives 8·136 for the diameter of the inside of the globe; consequently, $\frac{(8{\cdot}146-8{\cdot}136)}{2}=\frac{{\cdot}01}{2}={\cdot}005$, or $\frac{1}{200}$ of an inch is the thickness of the glass.

This question was also solved by the proposer; but he will observe by the above solution, that he committed a small error, by stating $\sqrt[3]{\frac{283}{{\cdot}5236}}=8{\cdot}2$, instead of 8·146, which materially affects the result.—ED.

To the Editor of the Artisan.

SIR,

Having observed in the last Number of your valuable publication (page 96) two questions by J. M. Edney, I have taken the liberty of offering you what I conceive to be a just solution, which if you think proper to insert in a future Number of the Artisan, will greatly oblige, your's, &c.

HUGH STARKE.

Ex. 1. The area of the circle is 706·86, and dividing this by 3·6339124, the area of the heptagon whose side is 1, we obtain 194·5176, the square of the side of the heptagon; and the square root of this is 13·946, which is the side of the heptagon required.

Ex. 2. Let $10x+y$ represent the number, the digits of which are x and y. Then from the first part of the question the following equation arises, $10x+y+54=10y+x$; and from the second part of the question arises the second equation, $y^2-x^2=60$; then the value of x being found in the 1st equation $=\frac{9y-54}{9}=y-6$, and that of x^2 in the second $=y^2-60$, the first value of x squared gives $x^2=y^2-12y+36=y^2-60$, or $12y=96$, or $y=8$; but $x=y-6$, or 2. Hence the number required is 28.

These two questions were also solved by the proposer; by Mr. A. Peacock, St. George's East; and the last one was also solved, very neatly, by Mr. J. Harding, Hart-street, Grosvenor-square; and Mr. George Futooye, High-street, Marylebone.

The solution of Charon's, and Mr. Graham's question, inserted on the same page of the "Artisan" with the two foregoing, will appear in our next.

The questions for solution in the present sheet are numbered so as to include all that have preceded them in the "Artisan;" and this plan will be continued, in order to prevent mistakes in their solutions, and to afford a ready method of referring to any particular question.—ED.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR,

Wishing to contribute to your valuable publication, as far as my humble abilities will allow, I enclose you the following question for insertion, if convenient, in your next Number. R. GRAHAM.

Ranelagh-st. Liverpool.

Quest. 12.—Given the versed sine 4, and the length of the arc 100, to find the diameter of the circle?

To the Editor of the Artisan.

SIR,

Please to insert the following question in one of your succeeding Numbers, which will very much oblige your obedient servant, H. FLATHER.

33, *Seymour-place, Bryanstone-square, April 5th,* 1824.

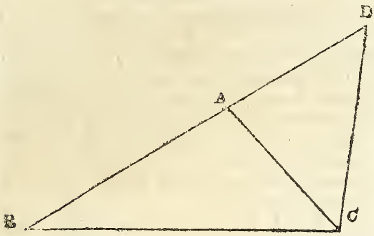
Quest. 13. What are the cubic contents of a space $43\frac{1}{2}$ inches long, 13 inches wide, and $7\frac{1}{2}$ inches deep. This being the quantity of water displaced by a model, on a scale of 1 foot to $\frac{1}{2}$ an inch; it is required to know how many cubic feet are contained in the said figure according to this scale?

GEOMETRY.

PROPOSITION XX.

THEOREM.—*Any two sides of a triangle are together greater than the third side.*

Let A B C be a triangle; any two sides of it together are greater than the third side; viz. the sides BA, A C, greater than the side B C; and A B, B C, greater than A C; and B C, C A, greater than A B.



Produce B A to the point D, and make A D equal to A C, and join DC.

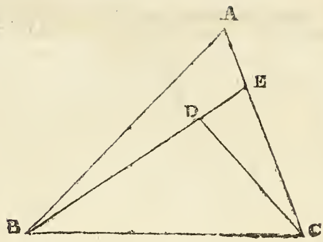
Because D A is equal to A C, the angle A D C is likewise equal to A C D; but the angle BCD is greater than the angle ACD; therefore, the angle B C D is greater than the angle A D C; and because the angle B C D of the triangle D C B is greater than its angle B D C, and that the greater side is opposite to the greater angle: therefore the side D B is greater than the side B C; but D B is equal to B A and A C together; therefore B A and A C together are greater than B C. In the same manner it may be demonstrated, that the sides A B, B C are greater than C A, and B C, C A, greater than A B. Therefore any two sides, &c. Q. E. D.

Dr. Simpson remarks, (from Proclus,) that " the Epicureans derided this proposition as being manifest to *asses;*" some of the moderns have done the same, but equally without reason: for, according to Euclid's plan, a *demonstration* was necessary. (See Prop. 3, obs. page 19.)

PROPOSITION XXI.

THEOREM.—*If from the ends of one side of a triangle there be drawn two straight lines to a point within the triangle, these two lines shall be less than the other two sides of the triangle, but shall contain a greater angle.*

Let the two straight lines B D, C D, be drawn from B, C, the ends of the side B C of the triangle A B C, to the point D within it; B D and D C are less than the other two sides B A and A C of the triangle, but contain an angle B D C greater than the angle B A C.



Produce B D to E; and because two sides of a triangle are greater than the third side, the two sides B A, A E, of the triangle A B E are greater than B E. To each of these add E C; therefore the sides B A, A C, are greater than B E, E C: Again, because the two sides C E, E D, of the triangle C E D are greater than C D, add D B to each of these; therefore the sides CE, E B, are greater than C D, D B; but it has been shewn that B A, A C, are greater than B E, E C; much more then are B A, A C, greater than B D, D C.

Again, because the exterior angle of a triangle is greater than the interior and opposite angle, the exterior angle B D C of the triangle C D E is greater than C E D; for the same reason, the exterior angle C E B of the triangle A B E is greater than B A C: and it has been demonstrated that the angle B D C is greater than the angle C E D; much more then is the angle B D C greater than the angle B A C. Therefore, if from the ends of, &c. Q.E.D.

It is essential to the truth of this proposition, that the straight lines drawn to the point within the triangle, be drawn from *the two extremities* of the base; for omitting this limitation, there are cases in which the sum of the two lines drawn from the base to a point within the triangle, will *exceed* the sum of the two sides of the triangle.

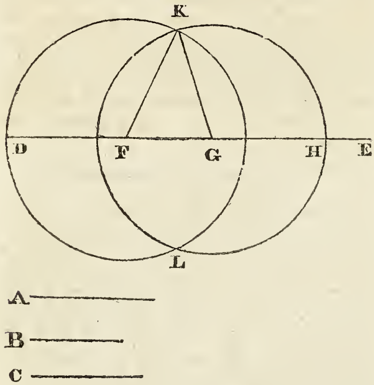
PROPOSITION XXII.

PROBLEM. — *To construct a triangle of which the sides shall be equal to three given straight lines; but any two whatever of these lines must be greater than the third.*

Let A, B, C be the three given straight lines, of which any two whatever are greater than the third; viz. A and B greater than C; A and C greater than B; and B and C than A. It is required to make a triangle of which the sides shall be equal to A, B, C, each to each.

Take a straight line D E terminated at the point D, but unlimited towards E, and make D F equal to A, F G to B, and G H equal to C: and from the centre F, at the distance F D, describe the circle D K L; and from the centre G, at the distance GH, describe another circle H L K; and join

KF, KG: the triangle KFG has its sides equal to the three straight lines A, B, C.

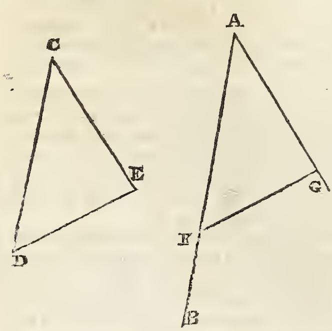


Because the point F is the centre of the circle DKL, FD is equal to FK; but FD is equal to the straight line A; therefore FK is equal to A: Again, because G is the centre of the circle LKH, GH is equal to GK; but GH is equal to C; therefore also GK is equal to C; and FG is equal to B; therefore the three straight lines KF, FG, GK, are equal to the three A, B, C: And therefore the triangle KFG has its three sides KF, FG, GK equal to the three given straight lines A, B, C. Which was to be done.

PROPOSITION XXIII.

Problem.—*At a given point in a given straight line, to make a rectilineal angle equal to a given rectilineal angle.*

Let AB be the given straight line, and A the given point in it, and DCE the given rectilineal angle; it is required to make an angle at the given point A in the given straight line AB, that shall be equal to the given rectilineal angle DCE.



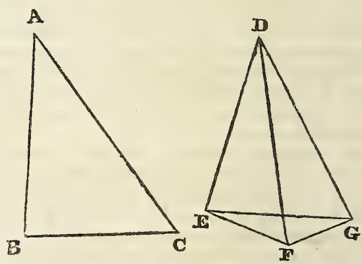
Take in CD, CE any points D, E, and join DE; and make the triangle AFG, the sides of which shall be equal to the three straight lines CD, DE, CE, so that CD be equal to AF, CE to AG, and DE to FG; and because DC, CE, are equal to FA, AG, each to each, and the base DE to the base FG: the angle DCE is equal to the angle FAG. Therefore, at the given point A in the given straight line AB, the angle FAG is made equal to the given rectilineal angle DCE. Which was to be done.

PROPOSITION XXIV.

Theorem.—*If two triangles have two sides of the one equal to two sides of the other, each to each, but the angle contained by the two sides of the one greater than the angle contained by the two sides of the other; the base of that which has the greater angle shall be greater than the base of the other.*

Let ABC, DEF be two triangles which have the two sides AB, AC, equal to the two DE, DF, each to each; viz. AB equal to DE, and AC to DF; but the angle BAC greater than the angle EDF: the base BC is also greater than the base EF.

Of the two sides DE, DF, let DE be the side which is not greater than the other, and at the point D, in the straight line DE, make the angle EDG equal to the angle BAC; and make DG equal to AC or DF, and join EG, GF.

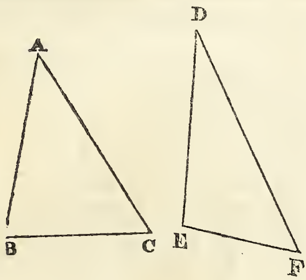


Because AB is equal to DE, and AC to DG, the two sides BA, AC, are equal to the two ED, DG, each to each, and the angle BAC is equal to the angle EDG; therefore the base BC is equal to the base EG; and because DG is equal to DF, the angle DFG is equal to the angle DGF; but the angle DGF is greater than the angle EGF: therefore the angle DFG is greater than EGF; and much more is the angle EFG greater than the angle EGF; and because the angle EFG of the triangle EFG is greater than its angle EGF, and that the greater side is opposite to the greater angle; the side EG is therefore greater than the side E F; but E G is equal to B C; and therefore also B C is greater than E F. Therefore, if two triangles, &c. Q. E D.

PROPOSITION XXV.

THEOREM.—*If two triangles have two sides of the one equal to two sides of the other, each to each, but the base of the one greater than the base of the other; the angle contained by the sides of that which has the greater base, shall be greater than the angle contained by the sides of the other.*

Let A B C, D E F, be two triangles which have the two sides A B, A C, equal to the two sides D E, D F, each to each; viz. A B equal to D E, and A C to D F: but the base C B is greater than the base E F; the angle B A C is likewise greater than the angle E D F.



For, if it be not greater, it must either be equal to it, or less; but the angle B A C is not equal to the angle E D F, because then the base B C would be equal to E F; but it is not; therefore the angle B A C is not equal to the angle E D F; neither is it less; because then the base B C would be less than the base E F; but it is not; therefore the angle B A C is not less than the angle E D F; and it was shewn that it is not equal to it: therefore the angle B A C is greater than the angle E D F. Wherefore, if two triangles, &c. Q. E. D.

The two last Propositions, as well as the 18th and 19th, are converse propositions.

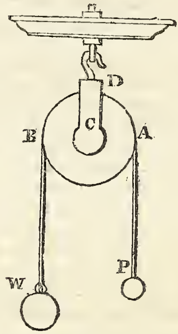
MECHANICS

OF THE PULLEY.

THE *pulley* is a wheel or cylindrical piece of wood, or any other hard substance, with a groove cut out of its rim, for the purpose of allowing a rope to pass over it. The cylinder moves round an axis, which works in a frame, called the block.

A system of pulleys, or a number of them combined together, is called a *muffle*, and is either fixed or *moveable*, according as the block which contains the pulleys is fixed or moveable. When the pulley is *fixed*, it gives no mechanical advantage, but serves merely to change the direction of the power applied to the cord which passes over it. There is, therefore, an equilibrium in the single *fixed* pulley when the power and weight are *equal*.

Let a power and weight P, W, equal to each other, act by means of a perfectly flexible cord P D W, which passes over the fixed pulley A D B;

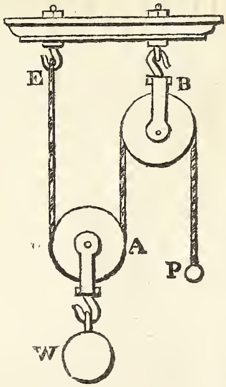


then whatever force is exerted at D, in the direction D A P, by the power, an equal force is exerted by the weight in the direction D B W; these forces will, therefore, keep each other in equilibrio.

This proposition is true in whatever direction the power is applied; the only alteration made, by changing its direction, is in the pressure upon the centre of motion.

When the pulley is *moveable*, one end of the cord is made fast to a fixed point; the power is applied to the other, and the weight hangs by the block in which the axis of the pulley is fixed.

Thus, a string fixed at E, passes under the moveable pulley A, and over the fixed pulley B;

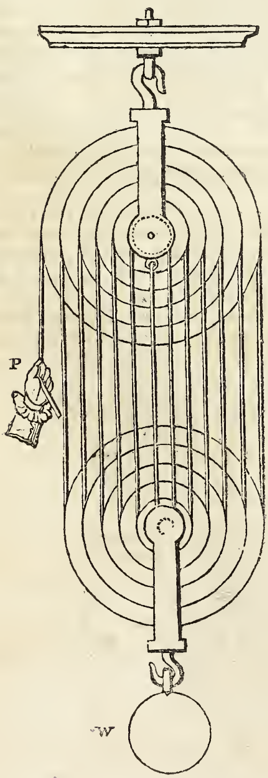


the weight is fixed to the centre of the block A, and the power is applied at P.

In a pulley of this kind, where the cords are parallel, the power is to the weight as 1 to 2; that is, a body of any given weight will balance another body double that weight. For, since the cords E A and B A are in the direction in which the weight acts, they exactly sustain it; and they are equally stretched in every point; therefore, they sustain it equally between them, or each sustains half the weight. Therefore P is to W, as 1 to 2, as already stated.

When the pulley is heavy, and acts in the same direction as the resistance, the weight of the pulley must be considered as part of the resistance. If the direction of the resistance be different from that in which the block hangs, the weight which it adds to the resistance, may be determined by the resolution of forces: see page 24th.

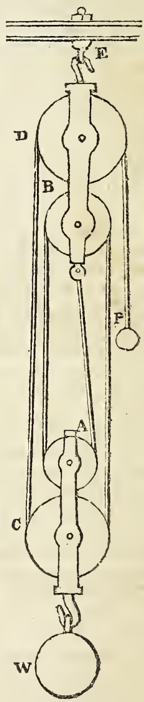
In a muffle, or system, where the same cord passes round any number of pulleys, and the parts of it between the pulleys are parallel, the power is to the resistance as 1 to the number of cords at the lower block.



For the force being equally communicated throughout the length of the cord, each portion will co-operate equally in supporting the weight, and will support that portion of it which is to the whole as 1 to the number of cords; consequently, a weight equal to that portion will retain any part of the cord in equilibrium, and with it the whole cord and the whole weight. And if the radii of the pulleys be taken in arithmetical progression, their angular velocity may be made equal *, and they may be fixed in the same axis, as in the annexed figure.

There is, however, various combinations of pulleys, where the same cord passes round all the pulleys; but the ratio of the power to the resistance is the same as that just stated.

The following figure represents another system of this description.

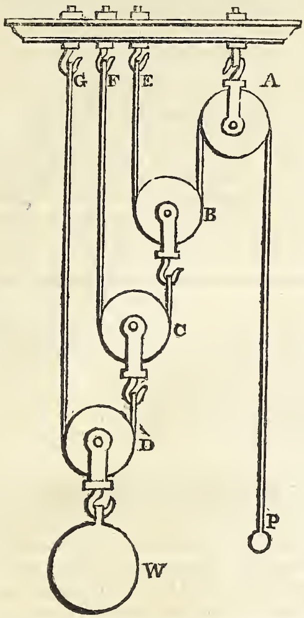


In a system where each pulley hangs by a separate string, and the strings are parallel, the power is to the weight as 1 to

* That is, the number of revolutions made by each will be in the inverse ratio of its radius.

that power of 2, whose index is the number of moveable pulleys.*

In the following system, a cord passes over the fixed pulley A, and under the moveable pulley B, and is fixed at E:

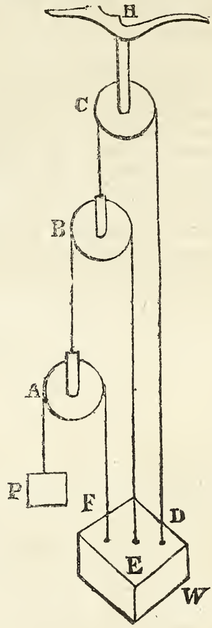


another cord is fixed at B, passes under the moveable pulley C, and is fixed at F, &c. in such a manner that the cords are parallel.

Here the number of moveable pulleys are three, and therefore the power is to the weight as 1 to 2, raised to the *third power*, that is, as 1 to 8; consequently when there are three moveable pulleys, there will be an equilibrium, if the power be *one-eighth* part of the weight.

In a system of pulleys, each hanging by a separate cord, where the cords are attached to the *weight*, as is represented in the following figure, the power is to the weight as 1 to the number 2, raised to that power whose index is the number of moveable pulleys, diminished by unity or 1.†

A cord fixed to the weight at F, passes over the pulley C, and is again fixed to the pulley B; another cord, fixed at E, passes over the pulley B, and is fixed to the pulley A, &c. in such a manner that the cords are parallel.



As the number of pulleys is here three, 2 raised to this power, and then diminished by 1, is 7; therefore the advantage gained is as 7 to 1, or there will be an equilibrium between the power and the resistance, when the power is *one-seventh* part of the weight or resistance.

When the cords are not parallel, the powers in each case, is to the corresponding pressure upon the centre of the pulley as the *radius* is to *twice the cosine* of the *angle* made by the cord with the direction in which the weight acts.* Also, by the resolution of forces, the power in each case, or pressure upon the former pulley, is to the weight it sustains, as the radius is to the cosine of the angle made by the cord with the direction in which the weight acts.

It is obvious, that the *pulley* is reducible to the *lever* of the *second kind*, or, still more directly, to the case of a body supported by two props, see page 56.

From being so extremely portable, and so applicable to cordage, the pulley is of all the mechanical powers the most useful at sea.

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* If any number be multiplied into itself any number of times, the products are called powers of that number; and the figure which denotes the number of times it has been multiplied by itself, is called the index of that power.

† See the preceding note.

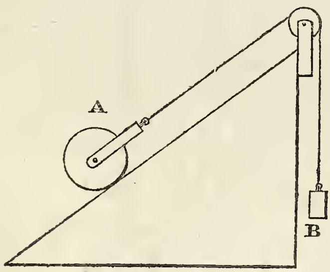
* To comprehend this proposition completely, it is necessary to have a slight knowledge of trigonometry. (See page 21, col. 2, and note.)

OF THE INCLINED PLANE.

The *inclined plane* is any plane surface which forms an angle with the horizon, and that angle is termed the *inclination* of the plane.

When a body is placed on an inclined plane, the force urging it to descend along the plane, is to the whole force of gravity, as the height of the plane is to its length, and therefore there will be an equilibrium when the power is to the resistance as the height of the plane to its length.

Thus, in the following figure, the weight of the body A, resting on the inclined plane, whose oblique length is to its height as 5 to 3, is sustained by a weight B, three fifths of the weight of itself.



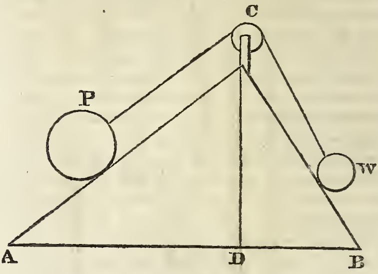
If bodies descend on any inclined planes of equal heights, but of different inclinations, the times of descent are as the lengths of the planes, and the final velocities are equal. Thus, a body will acquire a velocity of 32 feet in a second, after having descended 16 feet, either in a vertical or oblique direction; but the time of descent will be as much greater than a second, as the oblique length of the path is greater than 16 feet. This may be proved by experiment, allowing for the retardation by friction, the times being measured by a pendulum or stop watch.

There is a singular proposition, of a similar nature, which is still more capable of experimental confirmation; that is, that the times of falling through all *chords* drawn to the lowest point of a circle are *equal.*

If two or more bodies are placed at different points of a circle, and allowed to descend at the same instant along as many planes which meet in the lowest point of the circle, they will arrive there at the same time.

In order that a smaller weight may raise a greater to a given vertical height, in the shortest time possible, by means of an inclined plane, the length of the plane must be to its height as twice the greater weight to the smaller; so that the acting force may be twice as great as that which is simply required for the equilibrium. A body will therefore be raised on an inclined plane, in the shortest time possible, when its length is twice its height.

If two weights, P and W, sustain each other upon the planes A C and C B, which have a common altitude C D,



by means of a cord P C W, which passes over the pulley C, and is parallel to the planes, then P is to W as A C to B C; or the weight P multiplied into the length of the plane C B, is equal to the weight W multiplied into the length of the plane A C.

HYDRAULICS.

OF THE FORMATION OF WAVES.

When the surface of water is unequally pressed on, in parts contiguous to one another, the columns most pressed on are shortened, and sink beneath the natural level of the surface, while those that are least pressed on are lengthened, and rise above that level.

As soon as the former columns have sunk to a certain depth, and the latter have risen to a certain height, their motions are reversed, and continue so till the columns that were at first most depressed have become most elevated, and those that were most elevated, have become most depressed.

The alternate elevations and depressions thus produced, are called *waves.*

The water in the formation of waves has a vibratory or reciprocating motion, both in a horizontal and a vertical direction, by which it passes from the columns that are shortened to those that are lengthened, and returns again in the opposite direction, progressive motion not being necessary to undulation.

The vibrations of water in the form of waves, may be compared to the reciprocations of the same fluid in a syphon or bent tube;* and it was from this that Newton deduced the velocity of waves, and the time required for an undulation.

* See page 34, col. 1.

The *time* of an undulation, is the time from the wave being highest, at any point, to its being .highest at that point again. The *velocity* of the wave is the rate at which the points of greatest elevation or depression seem to change their places.

If the altitude and hreadth of a wave be known, the time of an undulation and the space which the wave appears to pass over may be determined as follows. To find the *time* of an undulation, add half the bread of the wave to its altitude, multiply the sum by ·3927, and the square root of the product will be the time in seconds.* Thus, suppose the breadth of a wave to be 14 feet, and its height 3 feet, required the time of an undulation. Here the sum of the height and half the breadth is 10, which multiplied by ·3927, becomes 3·927, the square root of which is 2, nearly, the number of seconds in which an undulation is performed.

To find the *space* which the wave passes over in one second:—Divide half the breadth of the wave by the square root of the sum of the altitude, and half the breadth, multiplied by 3·927, and the result will be the space passed over by the wave in one second.

Thus, suppose the breadth and height of a wave to be as stated in the preceding example, and it is required to find the space it will pass over in a second of time. Here the square root of 10 is 3·1, nearly, which multiplied by ·3927 is 1·22, nearly; and 7 divided by this number quotes $5\frac{3}{4}$, nearly, which is the space passed over in one second.

While the depth of the water is sufficient to allow the oscillation to proceed undisturbed, the waves have no progressive motion, and are kept, each in its place, by the action of the waves that surround it. But if by a rock rising near the surface, or by the shelving of the shore, the oscillation is prevented, or much retarded, the waves in the deep water are not balanced by those in the shallower, and therefore acquire a progressive motion in this last direction, and from *breakers*. Hence it is, that waves always break against the shore, whatever be the direction of the wind.

Breakers formed over a great extent of shore, are distinguished by the name of *surf*. The surf is greatest in those parts of the earth where the wind blows always nearly in the same direction: but in the foregoing observations, no allowance is made for winds.

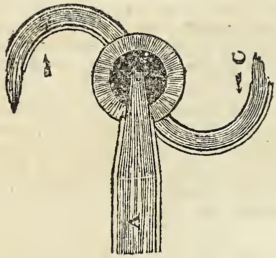
PERCUSSION AND RESISTANCE OF FLUIDS.

When a part of the weight of any fluid is expended in producing a motion in any direction, an equal force is deducted from its pressure on the vessel in that direction, for the weight employed in producing *motion* cannot at the same time be causing *pressure*; and when the motion produced is in any other diretion than a vertical one, its obliquity must be immediately derived from the re-action of the vessel, or of some fixed obstacle: for, it is obvious that a vertical, like that of gravity, cannot of itself produce an oblique or horizontal motion.

If a small stream descend from the bottom of a vessel, the weight expended in producing its motion is equal to that of a column of the fluid standing on a base equal to the contracted orifice, and of twice the height of the vessel. Thus, if the vessel be 16 feet high, the velocity of the stream will be 32 feet in a second, and a column, 32 feet in length, will pass through the orifice in each second, with the whole velocity deriveable from its weight acting for the same time: so much, therefore, of the pressure of the fluid in the reservoir must be expended in producing this motion, and must of course be deducted from the whole force with which the fluid acts on the bottom of the reservoir; in the same manner as when two unequal weights are connected by means of a cord passing over a pulley, and one of them begins to descend, the pressure on the pulley is diminished, by a quantity, which is as much less than the sum of the weights, as the velocity of their common centre of gravity is less than the velocity of a body falling freely. If the stream issue from the vessel in any other direction, the effect of the diminution of the pressure in that direction will be nearly the same as if the vessel were subjected to an equal pressure of any other kind in a contrary direction; and if the vessel be moveable, it will receive a progressive or rotatory motion in that direction. Thus, when a vessel or pipe is fixed on a centre, and a stream of water is discharged from it by a lateral orifice, the vessel turns round at first with an accelerated motion, but on account of the force consumed in producing the rotatory motion, in successive portions of the water, the velocity soon becomes nearly uniform. Thus, the following figure represents a cylinder, moveable on an axis with two curved pipes inserted in its lower part seen from above.

The stream A enters at the top of the cylinder, and is discharged by the orifices B and C, so as to turn the vessel in the direction B D. From similar reasoning it appears, that the effect of a detached jet on a plane surface perpendicular to it must be equivalent to the weight of a portion of the same stream equal in length to twice the height which is capable of producing

* This number is one-eighth of the circumference of a circle whose diameter is 1.



the velocity. And this result is confirmed by experiments: but it is necessary that the diameter of the plane be at least four times as great as that of the jet, in order that the full effect may be produced. When also a stream acts on an obstacle in a channel sufficiently closed, on all sides, to prevent the escape of any considerable portion of water, its effect is nearly the same as that of a jet playing on a large surface. But if the plane, opposed to the jet, be only equal to it in diameter, or if it be placed in an unlimited stream, the whole velocity of the fluid column will not be destroyed, it will only be divided and diverted from its course, its parts continuing to move on, in oblique directions, as represented in the following figure.

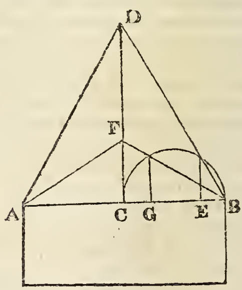
In such cases, the pressure is usually found to be simply equivalent to the weight of a column equal in height to the reservoir, the surface being subjected to a pressure nearly similar to that which acts on a part of the bottom of a vessel, while a stream is descending through a large aperture in another part of it.

It is obvious that in all these cases, the pressure varies as the square of the velocity, since the height required to produce any velocity is proportional to its square. This inference was first made in a more simple manner, from comparing the impulse of a fluid on a solid, with that of a number of separate particles, striking the surface of the body, each of which would produce an effect proportional to its velocity, while the whole number of particles, acting in a given time, would also vary in the same ratio. If the plane struck by the stream be itself in motion, the impulse is as the square of the *difference* of their velocities. Thus, if the velocity of a stream be 10 feet per second, and the plane on which it strikes retires from it at the rate of 8 feet per second, the impulse will only be equal to 4 feet, the square of the difference of the velocities.

Where the fluid is so confined that the whole of the stream acts on a succession of planes, each portion into which it is divided may be considered as an *inelastic solid*, striking on the surface exposed to it with a certain velocity; and in this case, the force must be considered as simply proportional to the relative *velocity*, and not to its square. For want of attention to this circumstance, the effects of water *wheels* have frequently been very erroneously stated.

When a jet, or stream of water, strikes a plane surface obliquely, its force, impelling the body forward, in its own direction, is found to be very nearly proportional to the height to which the jet would rise, if it were similarly inclined to the horizon. But when a plane is situated thus obliquely with respect to a wide stream, the force impelling it in the direction of the stream is somewhat less diminished by the obliquity, at least if we make allowance for its intercepting a smaller portion of the stream. Thus, if the anterior part of a solid be terminated by a wedge, more or less acute, the resistance, according to the simplest theory of the resolution of forces, might be found by describing a circle on half the base of the wedge, as a diameter, which would cut off a part from the oblique side of the wedge that would be the measure of the resistance, the whole side representing the resistance to the same solid without the wedge. But the resistance is always somewhat more than this, and the portion to be added may be found, very nearly, by adding to the fraction, thus found, one ten millionth part of the cube of the number of degrees contained in the external angle of the wedge.

Thus, in the following figure, where the whole resistance is directly opposed to the surface A B, is represented by B C,

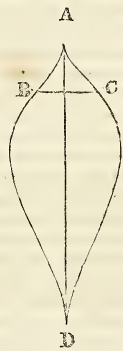


the portion which ought to act on the wedge

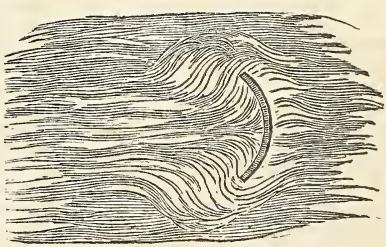
A B D*, is represented by B E; and in the same manner the resistance on A B F is to the whole as B G to B C.

When a body moves along the surface of a resisting medium at rest, or when an obstacle at rest is opposed to a fluid in equable motion, the pressure is increased before the moving substance, and diminished behind it; so that the surface is elevated at the one part, and depressed at the other, and the more as the velocity is greater. Now it is obvious that the pressure must be greatest where the elevation is greatest; and hence a perforation at the centre of the surface indicates a greater pressure than at the circumference. Behind the body this pressure becomes negative, and has sometimes been called non-pressure; hence it happens that a tube opening in the centre of the posterior surface, exhibits the fluid within it depressed below the level of the general surface of the water. Thus, if we suppose the velocity of a body, terminated by perpendicular surfaces, to be 8 feet in a second, it will require the pressure of about a foot to produce such a velocity; and we may therefore expect an elevation of about a foot before the body, and an equal pressure behind it; consequently an equivalent difference must be found in the pressure of the water at any equal depths on the anterior and posterior surfaces of the body. The water elevated before the body escapes continually towards each side, and the deficiency behind, is also filled up in some measure by the particles rushing in and following the body; but there is in both cases a certain quantity of water which moves forwards, and constitutes what is called the dead water; before, where it is usually most observable, it forms an irregular triangle, of which the sides are convex inwards. If the hinder part of the body be formed like a wedge, the water on each side will be advancing to fill up the vacuity, even while it remains in contact with the sides, and the negative pressure will be considerably diminished. For this reason, the bottoms of ships are made to terminate behind in a shape somewhat resembling a wedge; and the same economy may be observed in the forms of fishes, calculated by nature for following their prey with the greatest possible rapidity. In general, fishes, as well as ships, are of a more obtuse form before than behind;† but it is not certain that there would be any material difference in the resistance in a contrary direction, although some experiments seem to favour such an opinion. Perhaps if the natural form of the dead water, moving before an obtuse body, were ascertained, it might serve to indicate a solid calculated to move through the water with the least resistance; for the water must naturally assume such a form for its own motions, and the friction of fluids on solids being less than that of fluids moving within themselves, the resistance would be diminished by substituting a solid of the same form for a fluid.

Thus the form of the dead water moving before an obtuse body is nearly like that of A B C; and the form adapted for moving through the water with the least possible resistance, like A B C D.



It is found that no calculation deduced from experiments on the resistance opposed to oblique plane surfaces, will determine with accuracy the resistance to a *curved* surface. It appears, however, from experiment, that the resistance to the motion of a *sphere* is usually about two-fifths of the resistance to a *flat circular* substance of an equal diameter. The resistance to the motion of a *concave* surface is greater than to a plane, and the direction in which the particles of a fluid are supposed to move when they strike against a concave surface, are represented by the following figure.



* According to the principles of the resolution of forces. See page 24.

† This observation does not apply to the very extremities of these bodies.

Miscellaneous Subjects.

THE LIFE OF COPERNICUS.

Nicholas Copernicus was a native of Thorn, a city of note in Prussia Royal, where he was born January 19th, 1473. His father's name was Nicholas, and his mother was sister to Lucas Watzelrode, afterwards bishop of Warmia. He learnt the Latin and Greek languages, partly at home, and partly at the university of Cracow, where he studied philosophy, and sometimes medicine; at length he obtained the degree of Doctor. Meanwhile, as he was always extremely fond of the mathematics, he attended the lectures, private and public, of Albertus Brudzevius, a professor of that science in the same university. Of him he learnt the use of the Astrolabe, by which he got a good insight into astronomy, and at length he grew so emulous of the illustrious fame of Regiomontanus, that he resolved to follow him in all his steps. He cultivated every part of the mathematics, but applied himself more especially to perspective, by which means he became so complete a master in painting, that he drew his own picture, with a surprising likeness, before a glass. His view in learning to paint was, that, in his travels, especially through Italy, he might be enabled, not only to copy, but delineate with his own pencil whatever was worthy of his observation.

Being returned to Thorn, after a short stay, he set out for Italy, in the 23d year of his age, and proceeded to Rome, where, in a short time, his fame was little inferior to that of Regiomontanus. Here, in a full assembly of doctors and great men, he was instituted professor of the mathematics.

After some years spent at Rome, he returned to his own country, where, on account of his high attainments in learning, and the gentleness of his manners, he was affectionately received by his uncle, Lucas Watzelrode, bishop of Warmia; who, in order to give him the more leisure to pursue his mathematical studies, settled him in the college of Canons at Warmia, appertaining to his cathedral church. However, he was not suffered at first to enjoy his canonate in peace, as he often complains in his letters to his uncle, who remained at court, that he might be at hand to defend the public cause against the Cross-bearers and Teutonic knights; which so provoked them, that they libelled him publicly in the Dyet of Posnania. But at length, his own merit, together with that of his uncle, prevailed, and he obtained a peaceable possession. Upon which he instantly applied himself to three things in particular. One was, diligently to attend on divine offices: another, to attain so much skill in medicine, as to enable him to relieve the poor whenever they should want his assistance: thirdly, to employ the residue of his time in study. For which purpose he always chose solitude; and, except the affairs of the See, or the Chapter required it, never, but with reluctance, engaged in business, which he was on several occasions obliged to do.

But our principal regard will be to that part of his life which he devoted to contemplation and study; and as he affected nothing so much as the knowledge of the heavens and celestial bodies, for which his name is so highly celebrated, we shall relate in what order he began, and by what steps he proceeded to those attainments he acquired in this science.

In the first place, he observed, that astronomers, while they would maintain an equal motion in the celestial circumvolutions, took for it, or measured from, not a proper, but a wrong centre; namely, that of a circle called the equant. Nor could they collect the principal thing, that is, the form of the word, and its fine disposition, from that heap of hypotheses which they were forced to use. Wherefore he resolved to peruse as many of the books of philosophers and astronomers as he could lay his hands on, examine their several systems, and search out what was probable in them, that, from the whole, he might form a more exquisite harmony of the celestial motions, and symmetry of the parts of the world, than that which had been universally admitted.

As he knew that the Pythogoreans had removed the earth from the centre, and had placed therein the sun, the most noble of all bodies, he imagined he perceived somewhat of a beautiful order, if he might only be allowed to make a change, that is, to place the sun in the centre, and make the earth move round the sun. For Nicetas, Echphantus, Heraclides, and others, aimed well, who, though they detained the earth in the centre, yet gave it a motion, by which it turned on its own axis, like a sphere in a wheel, and daily perfecting a circuit from the west to the east, made the vicissitude of day and night, and assuming the office of the Primum Mobile,* discharged the sphere of the fixed stars, and all the planets from their rapid motion; so that the earth being turned to the east, all the stars must necessarily appear turned to the west, which nevertheless would appear very disproportionate. Wherefore Philolaus did much better, when, removing the earth from the centre, he gave it not only

* See Ptolemaic System, page 47.

a diurnal motion round its own axis, but an annual circuit round the sun; by which means it happens, that in traversing the zodiac, under whatever sign it is, the sun appears in opposition; so that the earth itself, Mercury, Venus, and the rest of the planets, must acknowledge the sun as their centre. But it seemed absurd to pluck the earth from the centre, and to give it such kind of motions. Copernicus, therefore, having variously canvassed the matter, and ascribed a triple motion to the earth, he thus writes: "By a close and long observation, I have at length found, that if the motions of the rest of the planets be compared with the circulation of the earth, and be computed for the revolution of each, not only their phenomena will follow, but it will so connect the orders and magnitudes of the planets, and all the orbs, and even heaven itself, that nothing in any part of it could be transposed, without the confusion of the rest of the parts, and of the whole universe."

This was about the year 1507. But he did not think it enough to establish a general ratio of hypotheses only, and according to it to solve phenomena in general; but he wanted likewise to conclude upon some special hypothesis, so as to define the periods of all motions, that from thence he might be able to erect tables for the heavens, preferable to the Ptolemaic; for which purpose, he judged it necessary to make observations, and by comparing them with those more ancient, he might attain to a greater precision. To this end he fabricated a quadrant, to be erected and applied to the meridian line above the plane of the horizon, that by the help of a shadow, from a cylindrical gnomon fixed at the centre, might be observed the greatest and least meridian altitude of the sun, in the summer and winter solstice; likewise for taking the distance of the tropics, and the altitude of either; also the altitude of the equator in the middle; likewise the altitude of the pole might thereupon be known, by estimating the altitude of the equator. He likewise constructed a parallactical instrument of fir wood, whose limb was divided into 1414 small parts or portions, marked with ink, to the end it might subtend the right angle of a quadrant, whose legs were four cubits long, consisting of 1000 of the same parts. The use of this was for observing the altitudes of any of the stars, particularly of the sun, not only when he is about the tropics, but also about the equinoxial; but especially in the spring, to observe his entrance into Aries. Likewise of the moon, but chiefly when she is in the northern limit, and that limit in Cancer, to find out her greatest latitude, also of Regulus, or of any other remarkable fixed star, in order to obtain the distance from the equinoxial point.

Being by these instruments furnished with many curious observations, he began to digest them in order, and undertook a work, which he finished, and divided into six books, entitled, "The Revolutions of the Celestial Orbs," which, in a geometrical point of view, included the whole science of astronomy.

The first book is divided into two parts; in the latter, he handles the doctrine of Sines, or chords, which he judged necessary in solving triangles, both plane and spherical: but in the former he has exhibited a general idea, or description of the world, agreeable to his own hypothesis, in which motion is attributed to the earth. In the first place, he teaches that the world is of a spherical form, and assigns this reason for it; because the sphere is the most perfect of all figures, and contains a greater quantity of space within it, than any other. He observes farther likewise, that fluid bodies naturally put on the figure of a sphere; that the sun, the moon, the planets, and all the heavenly bodies, are of that figure, and therefore, he concludes at once, that the figure of the visible world must be such likewise; though he is in all this plainly mistaken; because, properly speaking, the world has no figure at all, as it is not circumscribed, or bounded by any limits; and what we call the firmament is a mere *Ens Rationis*, or idea of the mind, and its spherical form is easily accounted for on the principles of optics; as we shall hereafter see. In this book, our author very much insists on the spherical figure of the earth, and its circular motion about the sun. He considers the reasons alleged by the ancients for placing the earth immoveably in the center of the system, and very learnedly and rationally confutes them; and having settled this point, and plainly proved the sun to possess the center of the system, he then treats of the celestial orbits, as those which the planets describe about the Sun, and illustrates the same by a diagram, which since this time has been usually called the Copernican System of the World.* He then treats of the twofold motion of the earth; viz. the diurnal motion about its axis, and its annual motion about the sun; and having dispatched the doctrine of plane and spherical trigonometry, he proceeds to

The Second Book. In this he considers the doctrine of the sphere, with a description of the various circles, great and small, that compose the same, with their various intersections and inclinations, one with another, in regard to the different in-

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* See page 77.

habitants of the globe. He considers the doctrine of right and oblique ascensions, the rising and setting of the sun and stars, the parts of time, and particularly of days and nights; after this, he gives an account of the instruments made use of for observing and correcting the places of the stars. He then proceeds to give us a new catalogue of the stars, found in the several signs and constellations, with the latitude, longitude, and magnitude of each particularly specified.

In the Third Book, he treats of the Equinoxes and Solstices, and gives us a history of observations, proving the inequality and precession of the same. He then treats of the variation of the obliquity of the Ecliptic, and shews, that it has been continually changing, and how it proceeds from the libration of the earth's axis. The quantity of this motion is then computed and digested, in tables. The times of the Equinoxes are more particularly enquired into, and investigated, the magnitude of the solar year, and the difference observed in the same; and tables of the equal and mean motion of the earth are computed for years, days, and sexagesimal parts. He then accounts for the apparent inequality of the sun's motion, with all the variety observed in the same. He then treats of the various Epochs, or times, from whence the ancient astronomers began to compute the mean motion of the sun; and having largely considered the nature and anomaly of the sun's motion, he gives us a table of the Prosthaphæresis or equation of the centre; so that, the difference between the true and mean anomaly is known for every part of the orbit, and, consequently, when one was given, the other might be from thence known. After this, he discourses on the Nychthemeron, or the nature and difference of the natural day of 24 hours, which concludes this book.

In the Fourth Book, he treats of the Lunar Motions, and considers the various hypotheses of the ancients concerning them: he corrects the errors of their grosser observations, and gives us a more particular and correct account of those motions, together with new tables of the same. After this, he very particularly enquires into the various differences and inequalities of the lunar motions. He farther shews how they are to be accounted for, according to the hypothesis of Cycles and Epicycles, which in those times they were obliged to make use of, for want of knowing the true theory of gravity, of which the first hints, however, were found in the books of this excellent writer. He expounds the doctrine of the lunar Prosthaphæresis, and gives us tables of the same; by which the apparent motion, or place of the moon, is found from the mean, or equal motion given. He considers then the motion of the moon, in latitude, of the quantity of the angle which the moon's orbit makes with the ecliptic. After this, we have a particular account of the construction of his Parallatic instrument, by which the horizontal parallax and distance of the moon from the earth, were much more accurately determined, than had been done before. From hence too, he was able to measure the diameter of the moon, and of the shadow of the earth at the moon's orb: also, he was hereby enabled to treat, in some measure, of the distance of the sun, as also, of the comparative magnitude of the sun, the moon, and the earth; which, though very inaccurate, were still much nearer the truth than any thing that had before this time been advanced upon the subject. Having insisted largely on these subjects, he proceeds to his observations on the apparent diameters of the sun and moon, with the various changes they underwent at different times. After this, he considers the different dimensions of the shadow of the earth, according to the Apogee, or Perigee, of the luminaries, and illustrates the same by proper diagrams. Then he insists largely on the doctrine of Parallaxes of the sun and moon, both in latitude and longitude, and gives us tables of the same. He then treats of the conjunctions and oppositions of the sun and moon, with regard to their mean and true times and places. Then the doctrine of Eclipses, both of the sun and moon, is learnedly explained, in regard to the manner in which they are produced, the times in which they happen, the quantity of duration, and the prognostics of the same; which closes the Fourth Book.

The Fifth Book considers the planetary motions, and their various affections. He gives us the number, their distances from the sun, and the times of their revolution, together with tables of their mean motions for years, days, hours, and minutes. After this, the particular theories of each planet are taught and illustrated by proper figures. He then gives an account of the distance of those planets from the earth, the apparent sides and excentricities of their orbits, the mean motions and anomalies, with the times or epochas from whence they have been computed for each planet, with the quantity of the same, in proper tables of the Prosthaphæresis, peculiar to the orbit of each; and having accounted for the various appearances and inequalities of their motions, in regard to their direct and retrograde motions and stations, he puts an end to the fifth book.

The Sixth Book is wholly spent in enquiring into, and ascertaining the latitude of the planetary orbits, or the inclination which they make with the ecliptic, their eccentricities, the places of their nodes, &c. and then the whole is concluded with tables of the latitude of each planet.

His book was printed at Nurimberg, in the year 1543, and till then, the world had never seen any thing that looked like a true system of astronomy. For what Ptolemy had done in his Almagestum Magnum, was entirely upon a false hypothesis, as we have already observed in treating of his system; and what had been performed by Regiomontanus and Purbachius, could be deemed no other than rude sketches, and outlines of the science; and though their writings were in great repute, we do not find Copernicus made the least use of them, since we find no mention of their names, or of their writings in the introduction to the present work, though Copernicus wrote many years after the Ephemerides of Regiomontanus, and the theories of Purbachius were published.

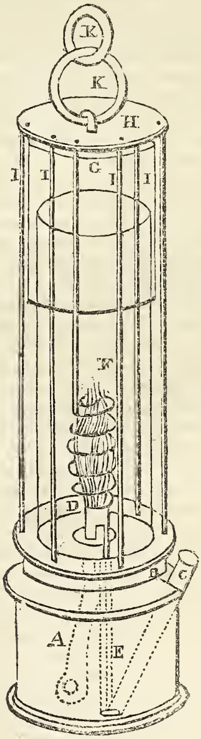
It appears from the writings of Gassendus, in the life of this author, that he finished this work about the year 1530; what he did afterwards, was only by way of correction, or Amendment of what he had before written.

The system of astronomy, however, contained in this great work, was at first looked upon as a most dangerous heresy, and although it had been long finished, yet he could not be prevailed upon to publish it, although strongly urged to it by his friends. At length, yielding to their entreaties, it was printed, and he had but just received a perfect copy, when he died the 24th of May, 1543, at 70 years of age; by which it is probable he was happily relieved from the violent fanatical persecutions which were but too likely to follow the publication of his astronomical opinions; and which indeed was afterwards the fate of Galileo, for adopting and defending them.

DESCRIPTION OF THE SAFETY LAMP OF SIR H. DAVY.

The gas which proves so destructive to miners is carburetted hydrogen, but the miners themselves call it fire-damp.

To obviate the destructive effects of this gas, when found in mines mixed with atmospherical air, Sir H. Davy turned his attention to the construction of a lamp which would prevent explosion; and upon the knowledge of the fact, *that flame cannot pass through apertures of small diameter*, he constructed what is now generally termed the safety-lamp, but by miners *the Davy*. The apertures in the gauze used in this lamp should not be more than $\frac{1}{20}$th of an inch square. As the fire-damp cannot be inflamed by ignited wire, the thickness of the wire is not of importance; but wire of $\frac{1}{40}$ to $\frac{1}{60}$ of an inch in diameter is the most convenient. If the wire of $\frac{1}{40}$ be found to wear out too soon, the thickness may be increased to any extent; but the thicker the wire, the more will the light be intercepted; for the size of the apertures must never be more than $\frac{1}{20}$ of an inch square. In the model which Sir H. Davy sent to the mines for use, there were 748 apertures in the square inch. The following is a figure of this lamp:



The foregoing figure represents the wire gauze safe-lamp. A, is the cistern which contains the oil; B, the rim in which the wire-gauze cover is fastened to the cistern by a moveable screw; C, an aperture for supplying oil, fitted with a screw or a cork; D, the receptacle for the wick; E, a wire for raising, lowering, or trimming it, and which passes through a safe tube; F, the wire-gauze cylinder, which should not have less than 625 apertures to a square inch; G, the second top, three quarters of an inch above the first; H, a copper-plate, which may be in contact with the second top; I, I, I, I, thick wires surrounding the cage to preserve it from being bent; K, K, are rings to hold or hang it by.

When the wire-gauze safe-lamp is lighted and introduced into an atmosphere gradually mixed with fire-damp, the first effect of the fire-damp is to increase the length and size of the flame. When the inflammable gas forms as much as $\frac{1}{20}$ of the volume of air, the cylinder becomes filled with a feeble blue flame; but the flame of the wick appears burning brightly within the blue flame, and the light of the wick continues, until the fire-damp increases to $\frac{1}{6}$ or $\frac{1}{5}$, when it is lost in the flame of the fire-damp, which in this case fills the cylinder with a pretty strong light. As long as any explosive mixture of gas exists in contact with the lamp, so long it will give light, and when it is extinguished, (which happens when the foul air constitutes as much as $\frac{1}{3}$ of the volume of the atmosphere,) the air is no longer proper for respiration. In cases where the fire-damp is mixed only in its smallest explosive proportion with air, the use of the wire-gauze safe-lamp, which rapidly consumes the inflammable gas, will soon reduce the quantity below the explosive point; and it can scarcely ever happen, that a lamp will be exposed to an explosive mixture containing the largest proportion of fire-damp; but even in this case, the instrument is absolutely safe; and should the wires become red hot, they have no power of producing explosion. Should it ever be necessary for the miner to work for a great length of time, in an explosive atmosphere, by the wire-gauze safe-lamp, it may be proper to cool occasionally by throwing water upon the top; or a little cistern for holding water may be attached to the top, the evaporation of which will prevent the heat from becoming excessive.

Gas in a state of combustion will not pass through brass-wire-gauze with apertures of certain dimensions, although the gas itself will pass through most readily when it is not in a state of combustion. If a piece of wire-gauze be held horizontally over the flame of a common gas-light, the flame of the gas will burn under the wire-gauze, but it will not pass through it in the state of flame. If, again, whilst the wire-gauze is held over the flame, a candle be applied to the upper surface of the gauze, the gas passing through it at the time will immediately take fire.

The reason of this singular fact is this,—gas must be heated to a certain degree, either by the immediate contact of flame or some other body, before it will either burn or explode; the gas in passing through the wire-gauze, loses a considerable portion of its heat, for the wire abstracts or conducts so much of it away, as to cool it below the degree at which it will burn or explode. This is what renders the safety-lamp of so much value, and in fact its whole utility rests upon this very singular circumstance. The wire-gauze with which the lamp is completely surrounded, cools the gas to a degree below the heat necessary to produce explosion, when burning in a mixture of atmospheric air and carburetted hydrogen gas.

CORRECTION OF THE BULK OF GASES FOR TEMPERATURE.

Some of our elementary treatises on chemistry contain an inaccurate mode of estimating the change of bulk in a gas, occasioned by variation of temperature. They have directed the bulk of the gas to be divided by 480, the quotient multiplied by the number of degrees by which the temperature of the gas differs from the temperature to which it is to be reduced, and the product *added* or *subtracted*, according as the actual temperature is below or above that referred to. But as the gas expands only $\frac{1}{480}$ of its bulk for each degree of Fahrenheit when its temperature is 32°, but at no other temperature, the rule is not correct, except when the gas is actually at 32°, and to be estimated at some other temperature. Mr. Briggs has pointed out this error, and has given the following rule, which is more correct:

Add the degrees which the gas is above 32° to 480, add also the degrees which the *required* temperature is above 32° to 480, then as the first number is to the second, so is the volume of the gas to the volume required.

Suppose, for example, that the temperature of 100 cubic inches of gas is 120° of Fahrenheit, and that it is required to find how much it would be diminished in volume, if its temperature were reduced to 62°. Here 88°, the excess of 120° above 32, added to 480 is 568; and 30°, the excess of 62 above 32°, added to 480 is 510: then as 568 is to 510 so is 100 cubic inches of gas to 90 inches nearly. It has therefore suffered a diminution of about $\frac{1}{10}$ of the whole.*

Another rule for making the correction is to add the number of degrees between 32° and the temperature of the gas to 480, divide the volume of the gas by the sum, and multiply the quotient (which will be the expansion for each degree), by the number of degrees between the temperature of the gas, and the required temperature; if the latter be greater than the former, *add* the product to the volume of gas; but if it be less *subtract* it; and the *corrected* volume will be obtained. As

* By the common rule the volume would have been reduced to about 82 cubic inches, or nearly one-fifth of the whole.

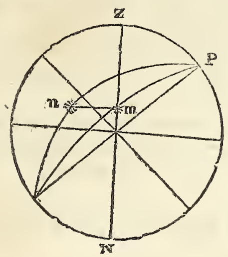
this rule gives the same result as the one used in the above example, it is unnecessary to give any illustration of it.

SOLUTIONS OF QUESTIONS.

To the Editor of the Artisan.

Sir,

If you deem the following solution of Boronesphilosmathematicus' question, at page 64, worthy of a place in your valuable publication, it is at your service.



Let Z in the above figure represent the zenith, P the North Pole, *m* the star Pollux, and *n* the middle star in Orion's belt. Then in the spherical triangle *n* P *m*, are given *m* P=61° 24′, and *n* P=91° 23′ the distance of the stars from the North Pole, and the included angle *n* P *m*=31° 30′, the difference of their right ascensions, to find the side *n m*=42° 30′.

Then by supposing a parallel to the horizon to pass through *n* till it meets Z *m* produced, a right angled triangle is thus formed, of which the hypothenuse *n m*= 42° 30′, and the difference of altitude of the stars=6° 35′ are given to find the other side *n* S=42° 5′.* Again, in the triangle Z *n s* right angled at S, are given the side *n s*, and the angle *n* Z *s*=51° the difference of the Azimuth of the two stars, to find Z *n*=59° 35′ from which 6° 35′ being subtracted, leaves Z *m*=53°; then in the triangle *m* Z P, right angled (the star *m* being supposed on the meridian) at Z, is given the side Z *m*=53° and the side *m* P=61° 24′ to find the side Z P=37° 18′ the co-latitude,—Hence the latitude of the place required, is 52° 42′ N.

This answer is different from that given by the proposer; but the Editor has not leisure to ascertain which of these answers are most correct; the proposer has however made an error in subtracting his colatitude (30° 10′) from 90°, for he makes the latitude 50° 49′ instead of 59° 50′.

* There is no letter *s* in the figure, neither are the lines *n s* or Z *n* drawn, owing to the figure being cut to answer the solution sent by the proposer, which we consider too complex and Algebraical for insertion in the present work.

To the Editor of the Artisan.

Sir,

Please insert the following solution of Charan's question, which appeared in page 96 of the Artisan, and oblige your obedient servant. A. B.

The whole quantity of water displaced, must be 231 × 10 + 216=2526 cubic inches; and 231×5 =1155 cubic inches, the quantity of brandy in the cask.

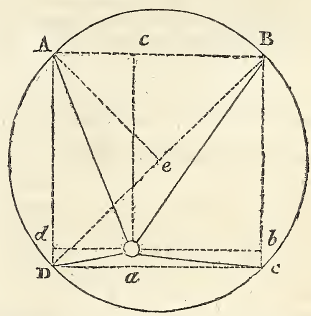
	in.	oz.	in.	oz.	
Now	1728 :	1000 : :	2526 :	1462	wt. of water.
And	1728 :	886 : :	1155 :	592	wt. of brandy.
	1728 :	800 : :	216 :	100	wt. of wood.

Then 1462—(592+100)=770 wt. of the water above that of the brandy and cask, which is the buoyant power to be counteracted by the lead; now 1 cubic inch of lead weighs 6· 554 ozs. and 1 cubic inch of water ·596 oz.; therefore 6·554—596=5·958, and

oz. oz.
5·958 : 770 : : 6·554 : 847 ozs.

or 53 lb. nearly of lead, the weight necessary to keep the cask under water.

The following is the proposer's (Mr. Graham) solution of his question, at page 96, which we insert with some additions, not having received any other solution.—Ed.



Let A B C D represent the circular plat of land, and O the situation of the pond required; inscribe the square and draw the lines, A O, B O, C O, and D O. Letfall the perpendiculars *a* O, *b* O *c* O and *d* O, and draw D B and let fall the perpendicular A *e* on it. Then by rule 12th in Bonneycastle's Mensuration $\left(\frac{10}{\cdot 7854}\right)^{\frac{1}{2}}$=3·567=D B (the diameter of the circle) and in his notes under the same rule 3·567 × ·7071=2·522= A B, B C, C D, or D A. Then (2·522) ²÷4 =1·59 the area of the triangle A *e* B, whence the triangle A *e* B taken from the sector *e* B A will leave ·91 the area of the respective segments separately. Again

$1-{\cdot}91={\cdot}09$, $2-{\cdot}91=1{\cdot}09$, $3-{\cdot}91=2{\cdot}09$ and $4-{\cdot}91=3{\cdot}09$ the areas of the triangles D O C, D O A, C O B, and B O A. Then $\frac{{\cdot}09\times2}{2{\cdot}522}$, $\frac{1.09\times2}{2{\cdot}522}$, $\frac{2{,}09\times2}{2{\cdot}522}$, and $\frac{3.09\times2}{2{\cdot}522}=$ ·0714,·8644,1·6574 and 2·45 $=a$ O, d O, b O and c O respectively; consequently make D $d=a$ O, C $a=b$ O join CD, and through c draw A B parallel to C D, and join D A and B C; then draw O A, O B, O C, and O D, and the thing is done.

To the Editor of the Artisan.

SIR,

Seeing a question in your last number, page 112, by H. Flather, I beg to submit the annexed solution to your notice, and am, Sir, your's, respectfully,

2, St. John Street, Clerkenwell. J. M. EDNEY.

The solid content of the space in cubical half inches is $=87\times26\times15=33930$: and as the scale of the model is to that of the figure itself as $\frac{1}{2}$ an inch to 1 foot. The solid content of the latter will be 33930 feet.

This question was solved exactly in the same manner by Mr. Futvoye, High-street, Mary-le-bone; it was also solved by the proposer, but in a very diffuse manner.

It may also be solved thus $43\frac{1}{2}\times13\times7\frac{1}{2}=4241\frac{1}{4}\div(\frac{1}{2})^3=33930$.—EDIT.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR,

Having myself in the early part of life been an operative mechanic, and am now very extensively employed as a civil engineer, I find the great advantage of having *studied geometry* when I was only a *journeyman* carpenter, and I am even convinced, that without a correct knowledge of the principles of *geometry*, we never can make any progress in the true principles and science of *mechanics*, nor in fact in any of the mechanical arts.

Feeling a great interest in the progress and success of the Artisans' and Mechanics' Institutions in London and elsewhere, I do by all means recommend my fellow artisans and mechanics to begin the *study of geometry* as soon as they become members of any of these useful institutions, as it is the foundation of all accurate science. Without having first obtained some knowledge of *geometry*, the lectures on *mechanics*, and other subjects delivered at those institutions, will be productive of very little benefit to those who may attend them.

Wishing to encourage and contribute as much as possible to so useful and cheap a publication as the "Artisan," and which is so well calculated for the self-instruction of mechanics in the scientific principles of their respective arts; I shall be obliged to you to insert the following geometrical problem in one of your succeeding numbers, and I shall occasionally send you such problems as I may conceive will prove most useful to Artisans and Mechanics generally.

I am, Sir, your obedient Servant,

Edinburgh, April 20, 1824. AN ENGINEER.

Quest. 14. Given the excess of the diagonal of a square above the side, to construct the square geometrically.

To the Editor of the Artisan.

SIR,

Please to insert the following question, if you think it worthy of a place in your valuable publication, which will oblige your's, &c.

JOHN BORONESPHILOSMATHEMATICUS.

Manchester, April 4, 1824.

Quest 15. Three men bought a grinding stone, 36 inches in diameter; and the thickness at the centre 4 inches, and at the circumference 12 inches, required how much must each man grind down of the stone's semi-diameter, so that each man may have an equal share thereof?

To the Editor of the Artisan.

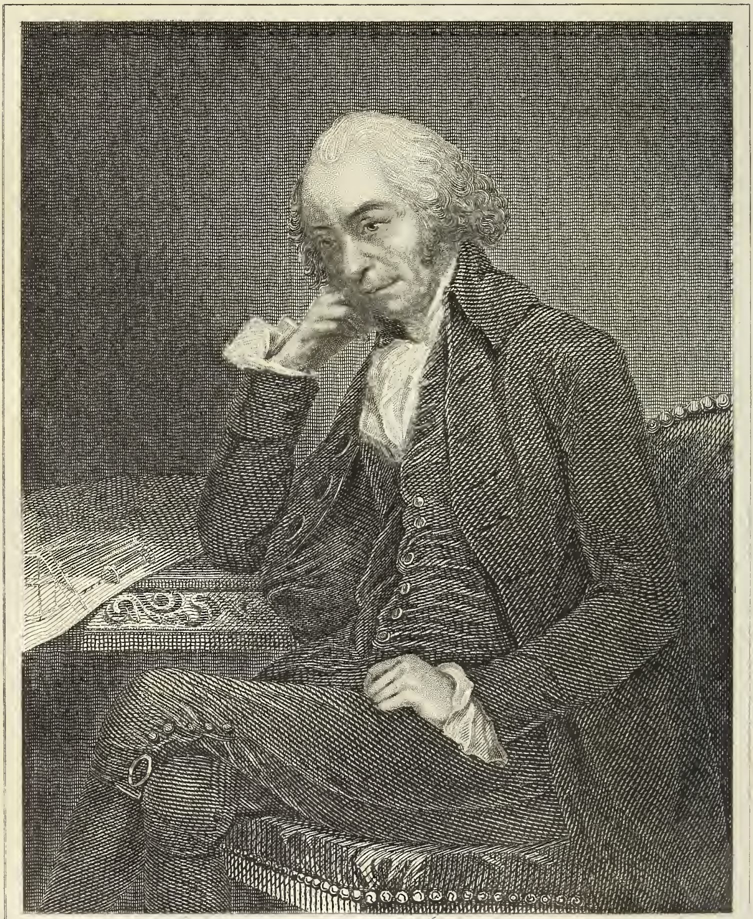
SIR,

If you have at any time, in a future number, a little corner to spare, please have the goodness to pop in the following simple question, as my landlord disputes my abilities of solving it, and you will oblige your well-wisher.

R. GRAHAM.

Quest. 16. My landlord having a little knowledge of science, and being rather (what the world calls) a man of taste, wishes to know how he must make an equilateral grass plat at the front of his house, that the area may be equal to the sum of the three sides?

ERRATA—The figures at page 107, in some copies, were by mistake inserted, instead of those at page 108, and *vice versa*.



M^r. JAMES WATT,

London, Published by Hodgson & C.o 10, Newgate St.

MEMOIR OF JAMES WATT, Esq. F.R.S.

In retracing the scientific tract, which has been trod by *inventive*, we might almost add *creative* genius, so closely are the advantages derived from some connected with the eventful times in which they lived, that it is next to impossible to do justice to the memories of the defunct, without naming them in conjunction. The meritorious exertions of Watt, both in his endeavours to dispel the mists which surrounded, and also to enlarge the hitherto contracted space in which the *mechanical powers* had moved, were productive of benefits peculiarly of this class. Engaged, as Great Britain then was, in a war of such magnitude, that arms became the profession of too large a portion of her able-bodied mechanics, some powerful substitute was absolutely necessary to supply the *defecit*. This Watt, and such as Watt, so ably contributed, by their inventions and applications of machinery to almost every branch of our manufactures and agriculture, which otherwise *must* have languished for want of means, that they might then justly have been denominated the Atlasses of British commerce. Descended from parents who, though not wealthy, merited honourable report, Watt was born at Greenock, in Scotland, A. D. 1735, where he was carefully educated; but having completed his grammatical studies and other important branches of education, he was at sixteen apprenticed to learn the art of an *Instrument Maker*, which consisted in the manufacture and repair of instruments used in philosophical and mechanical experiments, surgery, music, &c.; an art then confined to a limited sphere, and little encouraged. Having completed the period of his probation, he repaired to London, with anticipations both of improvement and employment; but after a lapse of little more than a year, he again sought his native country, where, on his arrival, he added measuring and surveying land to his former occupations. These, together, enabled him not only to live respectably, but likewise to pursue a course of *mechanical experiments*, which had previously been engendered in his prolific mind. It was now a fortunate incident gave that direction to the inventive powers of Watt, in which his provident imagination afterwards accomplished so much, and laid the foundation of his future fame. The model of Newcomen's steam engine, used in his lectures by the professor of natural philosophy at the University of Glasgow, was sent to Watt to be repaired; penetrating instantaneously into the future, he perceived the cabability of its improvement, and the great advantages to be derived from its general application to machinery; and although he continued to pursue his trade, it being his only source of subsistence, his genius ill brooked this restraint, but bent its whole force on his favourite subject, the improvement of the steam engine. This engine had now been in use more than half a century, but very little had as yet been done to perfect it. The first improvement which occurred to Watt, was the adoption of a *wooden* cylinder instead of a *metal* one; and to this he was led by observing that the *jet* of cold water conveyed into the piston, in order to *condense* the steam, cooled it to such a degree, that the steam introduced for the following stroke was *wasted* in restoring the heat; till this was remedied, it could not exert its entire powers. Many physical difficulties made him abandon his *first* idea for a more fortunate one—that of *passing* the steam into a *separate* condensing vessel, and thereby *never* cooling the cylinder. Necessity made him defer the application of his discovery; united at this period to an amiable companion, without fortune, his first concern was the means of subsistence. His friends, however, appreciated his invention, amongst whom was Dr. Roebuck, a gentleman possessing an enlightened understanding, as well as some property. He it was who associated himself with Watt, at this critical moment, in order to further his discovery, and to bring it to perfection. But their means soon exhausted, it was again on the eve of being abandoned, when, in 1773, Mr. Boulton, a gentleman of ample fortune, and very considerable proficiency in the sciences, became acquainted with, and saw the advantages of the invention. He liberally reimbursed Dr. Roebuck, and having previously erected a manufactory at Soho, near Birmingham, at a cost of 20,000 *l.* he took Mr. Watt with him to reside at that place, whose wife, having borne him two children, was then deceased. Watt was now possessed of leisure and means to realize any invention he might already be master of, or, by the exertion of his genius, bring to light. He found the advantage of condensing the steam under the piston in another vessel, but when the piston descended, he imagined the cylinder to be still cooled. His next important improvement was, to shut the top of the cylinder, and instead of pressing the piston down by the weight of the atmosphere, he applied the force of steam, and restored the *equilibrium*, by opening a communication between the upper and lower side of the piston. All that was afterwards accomplished by means of the *reciprocating steam engine*, was only to acquire perfection and easy management; but there was no departure from the first principle, nor did he ever depress the piston with steam more than one-tenth stronger than the atmosphere. What are now termed *high-pressure* engines, which have been productive of so many accidents, he did not countenance.

By this last improvement, his engineers fell into an error, which retarded the progress of the invention for some years; for, whenever the engine did not perform well, they stuffed the piston with *oakum*, till it required nearly the whole force of the steam to remove it into the cylinder. This defect was remedied; and Messrs. Boulton and Watt at length offered their engine to the proprietors of mines, on the most advantageous terms. Experiments were made by men in whom all parties could confide, with Newcomen's old engine, and Watt's improved one, in order to ascertain the value of the coals saved by the latter. This was done by placing a counter over the top of the beam or leaver, to tell the number of strokes; and then estimating according to the size of the cylinder. They were to receive but one-third of the coals saved; but the great obstacle to the introduction of their engine was, the incurring a fresh expense. This they removed by taking the old in exchange, at a considerable *loss*, and giving credit for the rest till the advantage was felt. By the adoption of these liberal means, they removed every difficulty; but it was not till the year 1778, that their engine began to be duly appreciated. In 1779 Watt invented a method of copying letters, which has been pretty generally adopted. In 1789, the Perriers, of Paris, applied to Messrs. Boulton and Watt for an improved steam engine, for the purpose of supplying that city with water. It was made at Birmingham, and sent to Chaillot to be put together, where it still remains. This circumstance the French have been at some pains to conceal; and M. Riche de Proney, an eminent mathematician, and chief of the school for roads and bridges in that country, ingeniously contrived to fill the pages of a quarto volume with a description of the improved steam engine, invented by our countryman, Watt, without once naming him; but the French will find it difficult to get any other nation, besides themselves, to wink at such injustice. The steam engine, as invented by Newcomen, and improved by Watt, had hitherto been employed only as a reciprocating power, for drawing water; but the genius of Watt did not permit him to stop there, he was for converting the *reciprocating* power into a *rotative* one, and thereby to render it of more general utility. To this end, various inventions were resorted to; but it did not occur to him, so ready is genius to imagine and encounter difficulties, that the simple method of a crank, as used in the turning of the old spinning wheel, might supply what he wanted to discover. He indeed meant to employ the crank, but wanted to make a further improvement by introducing a second axle, with a fly-wheel and heavy side, which should revolve twice during the time that the engine made one stroke; intending that the heavy side, when the piston was at the top, should be in the act of descending; not considering, that the heavy fly was a reservoir to preserve regular motion in the machine. Watt, which had been his usual custom from his first residence at Birmingham, gave directions for a model to be made according to this improvement, but as he never allowed a new invention to interrupt the progress of one reduced to actual practice, the consequence was, that which might have been brought to light in one, was eight months in hand; and, in the interim, a workman employed on the model communicated the invention to a Mr. Rickard, who was unprincipled enough to take out a patent for it; and, worked by one of Newcomen's engines but with the addition of this last discovery, a corn-mill was going on within a quarter of a mile of Watt, ere his model was completed. The above circumstances being ascertained by him, though he might easily have set aside the patent obtained by Mr. Rickard, neither he nor his partner being fond of legal remedies, he chose to seek one in his own brain. The only part of the last invention of any moment, and for which a substitute was absolutely necessary, was the *crank;* and here, with some expense, and a little ingenuity, he succeeded so well, that it is doubtful whether his substitute is not quite equal to the crank. This invention of the *rotative* motion by Watt, not only prevented the shock at the beginning and end of every stroke, by equalizing the motion, but rendered steam the most manageable, as well as the most useful of all powers, since it might be supplied of any power suited to the uses for which it might be required. Watt's last great improvement, which perfected his invention of the rotative motion, was to give the power which communicated the rotative motion, and moved in a portion of the circumference of a circle, an *accurately perpendicular* direction. This was not too great for the astonishingly pregnant imagination of Watt to accomplish; and he is said to have declared, that by what train of ideas he compassed this admirable invention, he himself was unable to communicate, so spontaneous were the powers of his genius. With this last invention terminated the most important of his labours. Soon after he settled at Birmingham, he married a second wife, a Miss M'Gregor, of Glasgow, a lady of considerable attainments, with whom he enjoyed a long and well-spent life of conjugal happiness. She bore him several children, but none of them are now surviving. Having passed his 70th year, about which period his partner, Mr. Boulton, died, he retired into private life, leaving the business to his own, only surviving, and Mr. Boulton's son, by whom the steam-engine manufactory is still conducted. Having arrived at his 84th year, he sunk into the arms of his Maker, (at his house at Heathfield, near Birmingham, August the 25th, 1819,) leaving behind him a name as imperishable as the universe, and a reputation which defies detraction. His genius was recognized by the Royal Societies of London and Edinburgh, of both of which he was made a member; nor let it be forgotten, that in 1808, when England and France were waging war with uncommon inveteracy, like Sir Humphrey Davy, he received the same honour from the National Institute of France.

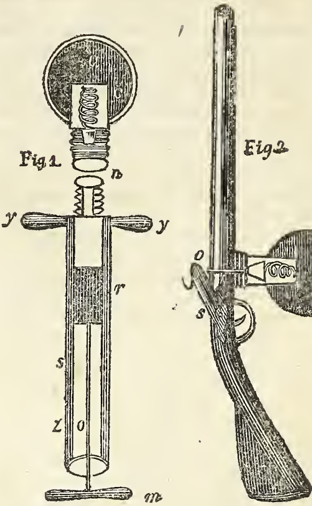
PNEUMATICS.

CONDENSED AIR.

THAT atmospherical air may be condensed into much less space, has already been stated at page 100, where there is also given the representation of a vessel for that purpose; we shall, therefore, now mention some of the effects which condensed air is capable of producing. One of the most striking of these effects is exhibited by means of an instrument called the *Air Gun*, an instrument which would actually answer the purpose of many guns, were the force of condensed air equal to that of gun-powder; but as it has never yet been condensed to such a degree as this explosive compound, the air-gun has never yet been applied to any useful purpose; it is however necessary that we should notice it in treating of condensed air.

This instrument derives its power from the elastic force of compressed air. As it is an instrument of some antiquity, and still occasionally used, we shall here give a representation of it, and also a short description of its construction.

A ball of cast steel, *a*, fig. 1st,



with a conical valve that opens inward, is screwed at *n*. upon the forcing syringe *s*, and is kept close shut by the spiral wire spring *c*. The syringe has a solid piston *r*, which can be drawn below the hole *z*, by placing the feet on the cross-bar *m*, and pulling by the two handles *y y*. The air will then fill the syringe through the hole *z*. If then the piston be forced to the top of the syringe, it will drive the air up before it into the ball *d*, which the valve will keep there. These strokes being repeated twenty or thirty times, will make the air within the ball ten or twelve times as dense as the common air, and to have the force of gunpowder. The ball now taken from the syringe, and screwed under the gun, fig. 2, will discharge twenty balls successively; for a pin, *o*, goes through the barrel of the gun, and terminates on the conical valve above mentioned; and the lock of the gun being cocked by the hook *s*, is discharged upon the pin *o*, by pulling at the trigger. The pin pushes open the conical valve, and lets out a small portion of air, but enough to force a ball through an inch board at thirty yards distance. This may be repeated twenty times with the same charge, and almost with the same force.

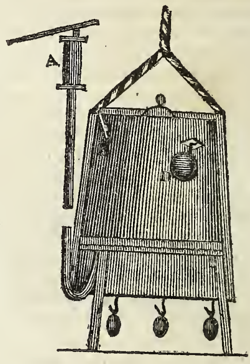
There is another instrument of this kind still more powerful than the one just described, called the *Magazine Wind-gun*; but it is more complex in its structure, and not so often to be met with, it is therefore unnecessary to give a particular description of it here.

The *Diving Bell* is also a machine which has the effect of condensing the air contained in it, when it descends into the water.

As this machine is found to be of very great use, in enabling engineers to perform many operations under water, which could not be effected by any other means, we shall give a description and representation of one of the most approved kind of these machines.

The principle upon which the diving bell becomes useful for the purpose intended, is that of air excluding every other body from the space it occupies. If a bell glass, for example, be pressed perpendicularly into water, with its mouth downward, the air in the glass will force the water down before it, and very little will enter the bell. Availing himself of this principle, Dr. Halley constructed a bell of copper, three feet in diameter at top, five feet at bottom, and eight feet in height, loaded at bottom with such a quantity of lead as to make the whole specifically heavier than its bulk of water. The bell was enlightened by a strong glass fixed in its top, where there was also a stop-cock to let out the heated air. This bell was lowered from the yard-arm of a ship, with two men in it, to the depth of ten fathoms. In their descent they found the water rise a little in the bell: the air about them condensed; which produced a disagreeable pressure on every part of their bodies, particularly on their ears, which seemed as if quills were thrust into them. They had light enough to see the pebbles at bottom, but it appeared red light, on every thing capable of reflecting it; the red part of light appeared to be the only part capable of forcing its way through the resisting or muddy medium in which they were placed. The air pressing through the pores of their skin, soon became as dense within their bodies as without, when the sense of pressure ceased, and they found no difficulty in remaining at the bottom several hours, where all was still and tranquil, though the surface was agitated with wind. Two barrels, filled with air, were alternately sent down to them, and the heated contaminated air was let out by the stop-cock, at the top of the bell. This bell, however, proved fatal to two men in the bay of Dublin, by that contraction which ropes suffer on being wet; this caused the bell to turn round in its descent, and entangle the strings by which the divers meant to ring bells, and indicate their wants to the people on board the ship from whence they were lowered. Waiting too long for these signals, the bell was raised, and the divers were both found dead; but not drowned; they died, like the unhapply people in the hole at Calcutta, by breathing contaminated air.

Instead of using barrels for supplying the divers with air, it is now the custom to force down a constant stream by means of a *pump*, resembling a *condenser* in its construction and operation. The heated air is suffered to escape by a stop-cock at the upper part of the bell. The following figure represents one of the diving bells now in use.



Here A is the forcing pump, B a stop-cock for letting out the heated air, C a strong glass for giving light, D a float for the security of the diver.

When proper care is taken to lower this machine gradually, the diver can support the pressure of an atmosphere twice or thrice the natural density.

As accidents may happen to the divers, even in the best regulated machines of this kind, it is highly proper that every diver should be provided with a float of cork, or with a hollow ball of metal, which might be sufficient to raise him slowly to the surface, in case of any accident happening to the bell, as several lives have been lost for want of this precaution, from confusion in the signals, and other causes, such as the one mentioned to the two men in the bay of Dublin.

Besides the form of this machine represented above, there are several other forms, but the mode of supplying them with air, and discharging the heated air, is nearly the same in all.

The late Mr. Walker constructed a small one of *wood*, for saving the wreck of the rich ship Belgioso, which was of a *conical* form, three feet diameter at bottom, two and a half at top, and three feet high, which was sunk by means of lead attached to its bottom.*

* Mr. Walker mentions a singular circumstance which happened to one of the divers, who went down in this bell. As there was plenty of air to spare in the bell, the diver thought that a candle might be supported in it, and he could descend by

Mr. Smeaton's diving bell at Ramsgate, was of cast-iron, and weighed 50 cwt. which was heavy enough to sink of itself. Its shape was a parallelopiped, four and a half feet long, three feet wide, and four and a half feet high, so that two men could work under it, and could see, by four strong glass lights at top. It was supplied with air in a similar manner to the one represented by the foregoing figure.

OF PUMPS.

The common sucking pump, used for raising water, may with propriety be described either under the head of Pneumatics or Hydraulics, as air and water are both necessary to its action. This useful machine consists of a tube open at both ends, in which is a moveable piston, bucket, or sucker, as large as the bore of that part of the tube in which it works. It is usually leathered round so as to fit the bore exactly, and prevent the escape of any air between it and the tube.

To render our explanation of the construction of this pump as useful as possible, we have represented it in the following figures as made of glass; by this means, both the action of the pistons, and operation of the valves, may be fully understood.

In figure 1st, *a* represents a ring of wood or brass,

Fig1.

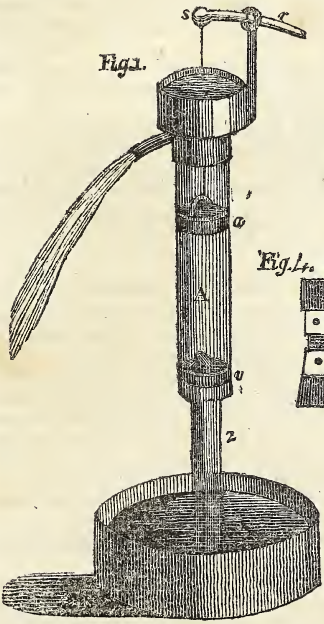


Fig2

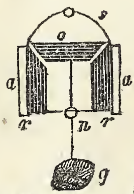
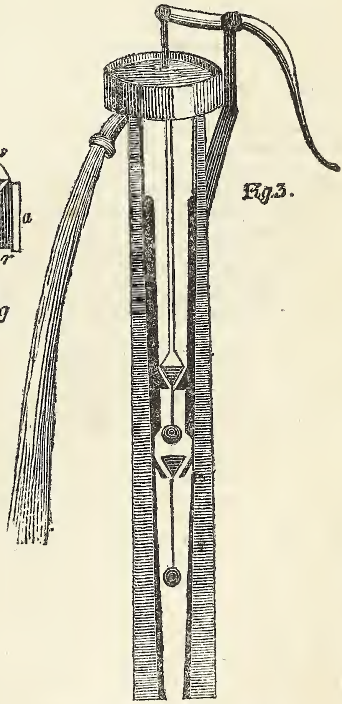


Fig.4.

Fig3.



with pliable leather fastened round it, to fit the cylinder A. Over the hole in this ring is a trap-door, or valve of metal, covered with leather, part of which often serves as a hinge for the valve to open and shut by. The handle and rod *r* end in a fork *s*, which, passing through the ring or piston, is screwed fast to it on the underside. Below this, and generally over a tube of a smaller bore, as *z*, is another valve *v*, opening upward, which will suffer water to pass up, but not down. Now, when the piston *a* is pulled up by the handle (its valve being close) the column of air on its top is lifted, and a vacuum underneath takes place; to supply this, the air, in the lower part of the pump, presses into the vacuum, and hence the

night. He made the experiment, and presently found himself surrounded by fish, some very large, and many such as he had never seen before; they sported about the bell, and *smelt* at his *legs*, as they hung in the water; this rather alarmed him, for he was not sure but some of the larger might take a *fancy* to *him*, he therefore rang his bell to be taken up, and the fish accompanied him, with much good nature, to the surface.

whole column of air *within* the pump becomes lighter than a similar column of air *without* the pump. By the superior pressure on the well, the water is forced into the pump, and through the valve *v*, which shutting, prevents its return. The piston being now forced down (as in the common act of pumping) through the water (which opens the piston valve), the next stroke lifts the water to the spout of the pump, and making a vacuum underneath, at the same time a fresh quantity is forced through the lower valve, which, if very tight, will keep the water there, so that the pump, remaining always full, water is delivered at its spout, on the first motion of the handle. As this effect is produced by the pressure of the atmosphere, and as it is found that a column of water, of about thirty-two or thirty-three feet high, is equal in weight to a column of air of the same base of forty-five miles high, (or to the height of the atmosphere,) therefore the piston *a* must always work at a less distance than thirty-two feet from the surface of the water; but if it were never to exceed twenty-eight feet it would be better, as the air varies considerably in its weight at different times, which must materially affect the rise of the water.

The force required for working a pump depends upon the height to which the water is to be raised, and the diameter of the bore of the pump in that part where the piston works.

If two pumps be of equal height, but the bore of the one double the diameter of the bore of the other, the widest will raise four times as much water as the other, and consequently will require four times as much force to work it.*

The wideness or narrowness of the pump in any other part than that in which the piston works, does not make the pump either more or less difficult to work, except what difference may arise from the friction of the water on the sides of the tube; this is however always greater in a narrow tube than in a wide one, on account of the greater velocity of the water.

Many attempts have been made to reduce both the friction and wearing of pumps; but it is evident that it is impossible to do away with the friction altogether; and that to work the pump, a force must be employed capable of overcoming the weight of the column of water raised by the piston, and of the weight of the piston itself, together with the friction of the water and piston on the sides of the tube.

The velocity of the stroke ought never to be greater than two or three feet, nor less than four inches in a second: the stroke should also be as long as possible, in order to avoid unnecessary loss of water during the descent of the valves. The diameter of the pipe through which the water rises to the barrel, ought not to be less than two thirds of the diameter of the barrel or pump itself.

Metallic conical valves are found to be great improvements in pump work. They are usually formed like the following figure, which represents a section of the whole piston: *o*, in figure 2, is the conical valve, ground very even and smooth to fit its cavity in the piston *a a*; it is kept in its cavity by the weight *g*, and directed into it by the wire acting through *n*, when lifted up by the water. The piston is leathered as usual, and the iron crane *s* goes through it, where it is fastened by the screw nuts *r r*. Both the upper and lower valves are made in this form: if well made, they are water-tight, and never wear.

The manner in which this valve is applied may be seen in the section of the pump, figure 3.

Figure 4 represents the common piston, coated with leather.

* This arises from the area of circles being to each other as the square of their diameters; for the square of 2 is 4.

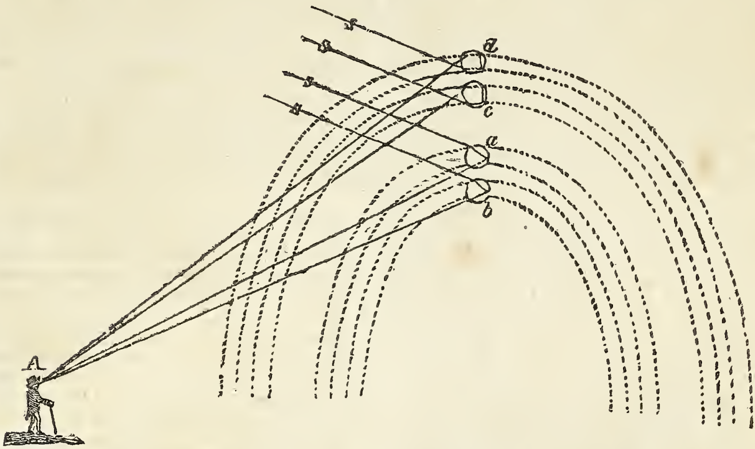
OPTICS.

OF THE RAINBOW.

The phenomena of the rainbow consists, as every person knows, of two bows, or arches, stretching across the sky, and tinged with all the colours of the prismatic spectrum. The internal or principal rainbow, which is often seen without the other, has the *violet* rays *innermost*, and the *red* rays *outermost*. The external, or secondary rainbow, which is much fainter than the other, has the violet colour outermost, and the red colour innermost. Sometimes supernumery bows are seen accompanying the principal bows.

As the rainbow is never seen unless when the sun shines, and when rain is falling, it has been universally ascribed to the decomposition of white light by the refraction of the drops of rain, and their reflection within the drops. The production of rainbows by the spray of waterfalls, or by drops of water scattered by a brush or syringe, is an experimental proof of their origin.

Let an observer be placed with his back to the sun, and his eye directed through a shower of rain to the part of the sky opposite to the sun. As the drops of rain are spherical particles of water, they will reflect and refract the sun's rays, according to the usual laws of refraction and reflection already explained in another part of this work. Thus in the following figure, where *s s s s* represent the sun's rays, and A the place of a spectator, in the centre of the two bows (the planes of which are supposed to be perpendicular to his view), the drops *a* and *b* produce part of the *inner* bow by two refractions and one reflection;



and the drops *c* and *d* part of the exterior bow, by two refractions and one reflection.

This holds good at whatever height the sun may chance to be in a shower of rain; if high, the rainbow must be low; if the sun be low, the rainbow is high: and if a shower happen in a vale when a spectator is on a mountain, he often sees the bow completed to a circle below him. So in the spray of the sea, or a cascade, a circular rainbow is often seen; and it is but the interposition of the earth that prevents a circular spectrum from being seen at all times, the eye being the vertex of a cone, whose base (the bow) is in part cut off by the earth.

It is only necessary, for the formation of a rainbow, that the sun should shine on a dense cloud, or a shower of rain, in a proper situation, or even on a number of minute drops of water, scattered by a brush or by a syringe, so that the light may reach the eye after having undergone a certain angular deviation, by means of various refractions and reflections, as already stated. The light which is reflected by the external surface of a sphere, is scattered almost equally in all directions, setting aside the difference arising from the greater efficacy of oblique reflection: but when it first enters the drop, and is there reflected by its posterior surface, its deviation never exceeds a certain angle, which depends on the degree of refrangibility, and is, therefore, different for light of different colours: and the density of the light being the greatest at the angle of greatest deviation, the appearance of a luminous arch is produced by the rays of each colour at its appropriate distance. The rays which never enter the drops produce no other effect, than to cause a brightness, or haziness, round the sun, where the reflection is the most oblique: those which are once reflected within the drop, exhibit the common internal or primary rainbow, at the distance of about 41 degrees from the point opposite to the sun: those which are twice reflected, the external or secondary rainbow, of 52°; and if the effect of the light, three times reflected, were sufficiently powerful, it would appear at the distance of about 42 degrees from the sun. The colours of both rainbows encroach considerably on each other; for each point of the sun may be considered as affording a distinct arch of each colour, and the whole disc, as producing an arch about half a degree in breadth, for each kind of light; so that the arrangement nearly resembles that of the common mixed spectrum.

A *lunar rainbow* is much more rarely seen than a solar one; but its colours differ little, except in intensity, from those of the common rainbow.

The appearance of a rainbow may be produced at any time, when the sun shines, as follows; opposite to a window, into which the sun shines, suspend a glass globe, filled with clear water, in such a manner as to be able to raise it or lower it at pleasure, in order that the sun's rays may strike upon it. Raise the globe gradually, and when it gets to the altitude of forty degrees, a person standing in a proper situation, will perceive a purple colour in the glass, and upon raising it higher the other prismatic colours, blue, green, yellow, orange, and red, will successively appear. After this, the colours will disappear, till the globe be raised to about fifty degrees, when they will again be seen, but in an inverted order; the red appearing first, and the blue, or violet, last. Upon raising the globe to about fifty-four degrees, the colours will totally vanish.

In the highest northern latitudes, where the air is commonly loaded with frozen particles, the sun and moon usually appear surrounded by *halos*, or coloured circles, at the distances of about 22 and 46 degrees from their centres. Several new forms of *halos* and *paraselenae*, or mock-moons, have been described by Captain Ross and Captain Parry. And Captain Scoresby, in his account of the Arctic Regions, has delineated an immense number of particles of snow, which assume the most beautiful and varied crystallizations, all depending more or less on six-sided combinations of minute particles of ice.

When particles of such forms are floating or descending in the air, there can be no difficulty in deriving from them those various and intricate forms which are occasionally met with among this class of phenomena.

Halos are frequently observed in other climates, as well as in the northern regions of the globe, especially in the colder months, and in the light clouds which float in the highest regions of the air. The halos are usually attended by a horizontal white circle, with brighter spots, or parhelia, near their intersections with this circle, and with portions of inverted arches of various curvatures; the horizontal circle has also sometimes *anthelia*, or bright spots nearly opposite to the sun. These phenomena have usually been attributed to the effect of spherical particles of hail, each having a central opaque portion of a certain magnitude, mixed with oblong particles, of a determinate form, and floating with a certain constant obliquity to the horizon. But all these arbitrary suppositions, which were imagined by Huygens, are in themselves extremely complicated and improbable. A much simpler, and more natural, as well as more accurate explanation, which was suggested at an earlier period by Mariotte, had long been wholly forgotten, till the same idea occurred to Dr. Young. The explanation given by the last mentioned philosophers is, that water has a tendency to congeal or crystallize in the form of a prism, and that the rays of light passing through these prisms (which are disposed in various positions,) by their own weight, are so refracted as to produce the different appearances which halos and parhelia have been observed to assume.

The colours which these phenomena exhibit, are nearly the same as the rainbow; but less distinct; the red being nearest to the luminary, and the whole halo being very ill-defined on the exterior side. Sometimes the figures of halos and parhelia are so complicated, as to defy all attempts to account for the formation of their different parts; but if the various forms and appearances which the flakes of snow assume, be considered, there will be no reason to think them inadequate to the production of *all* these appearances.

OF THE COLOURS OF NATURAL BODIES.

There is no branch of optics more difficult, and more generally interesting, than that which relates to the *colours* of natural bodies.

The splendid tints with which nature has enriched the vegetable, the mineral, and the animal kingdom, have attracted the admiration even of the rudest minds, and have long formed a subject of perplexing research to the natural philosopher.

One of the finest results of Newton's experiments on the colours of thin plates, was their application to the explanation of the colours of *natural bodies*. We shall, therefore, endeavour to give a general view of the principles upon which that celebrated philosopher's hypothesis rests.

His general position is, that if the sun's light consisted only of *one sort of rays*, there would be but *one colour* in the whole world; and that it would be impossible to produce any new colour, either by reflection or refraction; consequently the variety of colours, is owing to the composition of light, or to light being a compound body.

Homogeneous light that appears *red*, or rather makes objects appear so, Newton calls *red-making* rays, that which makes objects *yellow*, *green*, *blue*, &c. he calls *yellow-making*, *green-making*, *blue-making*, &c.* The surface of transparent bodies *reflects* the greatest quantity of light when their *refractive* power is *greatest*, whether the surface is in contact with air, or separate two *media* of different refractive powers. When the two media have the same refractive powers, there is no reflection at their separating surfaces, and the quantity of reflected light always increases with the difference of the refractive powers.

This proposition is established by numerous experiments. *Ruby-silver*, *red-spar*, *diamond*, and several other substances, have a much higher lustre, or reflect much

* See note, page 102; and page 103, col. 2d.

more light than any other substance; and ice and water reflect less light than almost any other substance possessed of a refractive power.

If in the manufacture of glass the refractive power be increased, by adding lead, the lustre, or reflective power, will be increased at the same time: and in like manner, if alcohol be added to water, the lustre of the compound will be increased with its refractive power.

If water be poured upon a surface of *crown glass*, the reflective power of the surface will be greatly diminished. If alcohol be poured upon it, the reflective power will be diminished still more.

The least or thinnest parts of almost all natural bodies are in some measure transparent, and the opacity of any body arises from the reflections caused in its internal parts.

The transparency of *gold* and *silver*, when reduced into thin leaves, and of all metalic particles, either when in a state of solution, or when in the form of crystallized salts, may be considered as a proof of the proposition which has just been stated.

Substances, too, that appear perfectly black to the eye, become translucent,* and even transparent, when reduced very thin, and exposed to a strong light.

Between the parts of opaque and coloured bodies, there are many spaces, either empty, or filled with media of different densities, as water, for example, as well as the aqueous globules that constitute clouds or fogs. The truth of this will appear from considering what has already been said on this subject; for there are numerous reflections with bodies, which cannot happen unless there were interstices between their particles, and of at different refractive power. Besides there are many opaque substances which become transparent, by filling their pores with any substance of nearly the same density with their parts; thus *paper*, *vellum*, and various other bodies, become almost transparent by absorption of *oil* or other fluids of nearly the same refractive power. On the contrary, all these bodies become opaque when the water or fluid has escaped from their pores. The substance *Iodine*, which reflects light exactly like metals, is perfectly opaque; but when it is thrown off into vapour by heat, it forms a purple coloured gas, which consists of the solid transparent particles of iodine floating with air between them. When a mixture of turpentine and water, or of water and air, is effected, the compounds become perfectly white and *opaque*, in consequence of the reflection of light at the particles of turpentine and water, and at the junction of the bubbles of froth, with the air which they enclose.

The transparent parts of bodies, according to their several sizes, reflect rays of one colour, and transmit those of another, for the same reason that thin plates of air and water reflect or transmit those rays.

Sir Isaac Newton conceives, that the *parts* of all natural bodies exhibit the same colours as the bodies themseves, on the same principle that the parts of a film or leaf of uniform thickness and colour, have the same colour as the film, even when slit into threads, or broken into fragments, that preserve their thickness. The coloured plumage of birds vary their tints at the same place, by varying the position of the eye, in the same manner as thin plates, and hence the tints arise from the slenderness of the fine hairs which grow out of the feathers. In like manner, the colours of silks, cloths, &c. when penetrated by water or oil, become more faint by immersion in these liquors, and again recover their original colours when they are dry. *Leaf-gold*, some kinds of painted glass, and the infusion of *lignum nephriticum*, reflect one colour, and transmit another, like thin plates, and the coloured flowers of plants and vegetables usually became more transparent, or in some degree change their colours by being bruised. The change of colours produced by mixing different fluids, is ascribed by Sir Isaac Newton to a change of bulk, and of density in the saline particles of the liquor, in consequence of the mutual action. A coloured fluid, for example, may occur transparent, if its particles are by any means divided into smaller ones; and, on the contrary, two transparent fluids may compose a coloured one, by the association of the particles into one cluster.

The colour of a body depends on the rays incident, or which fall upon it at all angles, and a slight variation in the obliquity at which they fall on it, will alter the reflected tint to various colours, when the particles are rarer than the surrounding medium, to a much greater extent than when particles are more dense than that medium, and it is probable that the particles are the densest.

* A body is said to be translucent when it admits the light to pass through it; and transparent when *objects* can be seen through it.

CHEMISTRY.

Phosphorus, when pure, is semi-transparent, and of a yellowish colour; but when kept some time in water, it becomes externally opaque, and then has a great resemblance to white wax. Its consistence is nearly that of wax. It may be cut with a knife, or twisted to pieces with the fingers.* It is insoluble in water, but it melts at the temperature of 100°. Its mean specific gravity is 1·770.

Care must be taken to keep phosphorus always under water, particularly when melted; for it is so combustible, that it cannot easily be melted in the open air without taking fire. When phosphorus is newly prepared, it is always dirty, being mixed with a quantity of charcoal dust and other impurities. These impurities may be separated by melting it under water, and then squeezing it through a piece of clean shamoy leather. It may be formed into sticks, by putting it into a glass funnel with a long tube, stopped at the bottom with a cork, and plunging the whole under warm water. The phosphorus melts, and assumes the shape of the tube. When cold, it may be easily pushed out with a bit of wood.

If air be excluded, phosphorus evaporates at 219°, and boils at 554°.

When phosphorus is exposed to the atmosphere, it emits a white smoke, which has the smell of garlic, and is luminous in the dark. This smoke is more abundant the higher the temperature is, and is occasioned by the gradual combustion of the phosphorus, which at last disappears altogether.

When a bit of phosphorus is put into a glass jar filled with oxygen gas, part of the phosphorus is dissolved by the gas at the temperature of 60°; but the phosphorus does not become luminous unless its temperature be raised to 80°. Hence we learn, that phosphorus burns at a lower temperature in common air than in oxygen gas. This slow combustion of phosphorus, at the common temperature of the atmosphere, is what renders it necessary to be kept in phials filled with water. The water should be previously boiled to expel a little air, which that liquor usually contains. The phials should be kept in a dark place; for when phosphorus is exposed to the light, it soon becomes of a white colour, which gradually changes to a dark brown.

When heated to 148°, phosphorus takes fire and burns with a very bright flame, and gives out a great quantity of white smoke, which is highly luminous in the dark. It leaves no residuum; but the white smoke, when collected, is found to be an *acid*. Stahl considered this acid as the muriatic.* According to him, phosphorus is composed of muriatic acid and phlogiston,† and the combustion of it is merely the separation of phlogiston. He even declared, that, to make phosphorus, nothing more is necessary than to combine muriatic acid and phlogiston.

These assertions having gained implicit credit, the composition and nature of phosphorus were considered as completely understood, till Margraf of Berlin published his experiments in the year 1740. That great man, one of those illustrious philosophers who have contributed so much to the rapid increase of the science, distinguished equally by the ingenuity of his experiments and clearness of his reasoning, attempted to produce phosphorus by combining together phlogiston and muriatic acid: but though he varied his process a thousand ways, presented the acid in many different states, and employed a variety of substances to furnish phlogiston, all his attempts failed, and he was obliged to give up the combination as impracticable. On examining the acid produced during the combustion of phosphorus, he found that its properties were very different from those of muriatic acid. It was therefore a distinct substance. The name of *phosphoric acid* was given to it; and it was concluded that phosphorus is composed of this acid united to phlogiston.

But it was observed by Margraf, that phosphoric acid is heavier than the phosphorus from which it was produced; and Boyle had long before shewn, that phosphorus would not burn except when in contact with air. These facts were sufficient to prove the inaccuracy of the theory concerning the composition of phosphorus; but they remained themselves unaccounted for, till Lavoisier published those celebrated experiments which threw so much light on the nature and composition of acids.

He exhausted a glass globe of air by means of an air-pump; and after weighing it accurately, he filled it with oxygen gas, and introduced into it 100 grains of phosphorus. The globe was furnished with a stop-cock, by which oxygen gas could be admitted at pleasure. He set fire to the phosphorus by means of a burning glass. The combustion was extremely rapid, accompanied by a bright flame and much heat. Large quantities of white flakes

* This being rather a dangerous operation, water ought to be at hand to plunge it into as soon as it begins to smoke.

* This acid will be afterwards described.

† The term *phlogiston* was applied by Stahl and his followers to a substance, which, according to them, exists in all combustible bodies, and separates during combustion.—See page 15, col. 2.

attached themselves to the inner surface of the globe, and rendered it opaque; and these at last became so abundant, that, notwithstanding the constant supply of oxygen gas, the phosphorus was extinguished. The globe, after being allowed to cool, was again weighed before it was opened. The quantity of oxygen employed during the experiment was ascertained, and the phosphorus, which still remained unchanged, accurately weighed. The white flakes, which were nothing else than pure phosphoric acid, were found exactly equal to the weights of the phosphorus and oxygen which had disappeared during the process. Phosphoric acid, therefore, must have been formed by the combination of these two bodies; for the absolute weight of all the substances together was the same after the process as before it. It is impossible, then, for phosphorus to be composed of phosphoric acid and phlogiston, as phosphorus itself enters into the composition of that acid.

Thus the combustion of phosphorus, like that of hydrogen and carbon, is nothing else than its combination with oxygen: for during the process no new substance appears, except the acid, accompanied indeed with much heat and light.

From Lavoisier's experiment it follows, that 100 parts of phosphorus during this combustion, unite with 154 parts of oxygen. So that a grain of phosphorus condenses no less than $4\frac{1}{2}$ cubic inches of oxygen gas; and five grains are capable of depriving $102\frac{1}{4}$ cubic inches of air of all its oxygen gas.

Though pure phosphorus does not take fire till it be heated to 148°, it is nevertheless true, that we meet with phosphorus which burns at much lower temperatures. The heat of the hand often makes it burn vividly and it even takes fire when merely exposed to the atmosphere. In all these cases the phosphorus has undergone a change. It is believed at present, that this increase of combustibility is owing to a small quantity of oxygen with which the phosphorus has combined. Hence, in this state, it is distinguished by the name of *oxide of phosphorus*. When a little phosphorus is exposed in a long narrow glass tube to the heat of boiling water, it continues moderately luminous, and gradually rises up in the state of a white vapour, which lines the tubes. This vapour is the *oxide* of phosphorus. This oxide has the appearance of fine white flakes, which cohere together, and is more bulky than the original phosphorus. When slightly heated it takes fire, and burns brilliantly. Exposed to the air, it attracts moisture with avidity, and is converted into an acid liquor. When a little phosphorus is thus oxidized in a small tin box by heating it, the oxide acquires the property of taking fire when exposed to the air. In this state it is often used to light candles, under the name of *phosphoric matches*; the phosphorus being sometimes mixed with a little oil, sometimes with sulphur. But the simplest mode of making matches of this kind is, to put a little phosphorus, dried by blotting-paper, into a small phial; to heat the phial, and when the phosphorus is melted, to turn it round, so that the phosphorus may adhere to the sides. The phial is then to be closely corked and prepared for use. On putting a common sulphur-match into the bottle, and stirring it about, the phosphorus will adhere to the match, and will take fire when brought out into the air.

When bits of phosphorus are kept for some hours in hydrogen gas, part of the phosphorus is dissolved. This compound gas, to which Fourcroy and Vauquelin, the discoverers of it, have given the name of *phosphorized hydrogen gas*, has a slight smell of garlic. When bubbles of it are made to pass into oxygen gas, a very brilliant blueish flame is produced, which pervades the whole vessel of oxygen gas. It is obvious that this flame is the consequence of the combustion of the dissolved phosphorus.

When phosphorus is introduced into a glass jar of hydrogen gas standing over mercury, and then melted by means of a burning glass, the hydrogen gas dissolves a much greater proportion of it. The compound thus formed has received the name of *phosphuretted hydrogen gas*. It was discovered, in 1783, by Mr. Gengembre, and afterwards by Mr. Kirwan, before he knew of the experiments of Gengembre.

It has a very fetid odour, similar to the smell of putrid fish. When it comes into contact with common air, it burns with great rapidity; and if mixed with that air, detonates violently. Oxygen gas produces a still more rapid and brilliant combustion than common air. When bubbles of it are made to pass up through water, they explode in succession as they reach the surface of the liquid; a beautiful coronet of white smoke is formed, which rises slowly to the ceiling. This gas is the most combustible substance *known*.

Pure water, when agitated in contact with this gas, dissolves at the temperature of between 50° and 60° about the fourth part of its bulk of it.* The solution is of a colour not unlike that of roll sulphur; it has a very bitter and disagreeable taste, and a strong unpleasant odour. When heated nearly to boiling, the whole of the phosphuretted hydrogen gas is driven off

* Mr. Henry, however, found, that 100 inches of water took up only 2·14 inches of this gas at the temperature of 60°.

unchanged, and the water remains behind in a state of purity. When exposed to the air, the phosphorus is gradually deposited in the state of oxide; the hydrogen gas makes its escape; and at last nothing remains but pure water.

When electric explosions are passed through this gas, its bulk is increased precisely as happens to carburetted hydrogen. The water which it contains is decomposed, phosphoric acid formed, and hydrogen gas evolved.

Phosphorus is capable of combining with carbon. This compound, which has received the name of *phosphuret of carbon*,* was first examined by Mr. Proust, the celebrated professor of chemistry, in Spain. It is the red substance which remains behind when new-made phosphorus is strained through shamoy leather. In order to separate from it a small quantity of phosphorus which it contains in excess, it should be put into a retort, and exposed for some time to a moderate heat. What remains behind in the retort is the pure phosphuret of carbon. It is a light flocky powder, of a lively orange-red, without taste or smell. When heated in the open air it burns rapidly, and a quantity of charcoal remains behind. When the retort in which it is formed is heated red hot, the phosphorus comes over, and the charcoal remains behind.

Such are the properties of phosphorus, and the compounds which it forms with oxygen, hydrogen, and carbon. It is capable, likewise, of combining with many other bodies: the compounds produced are called *phosphurets*.

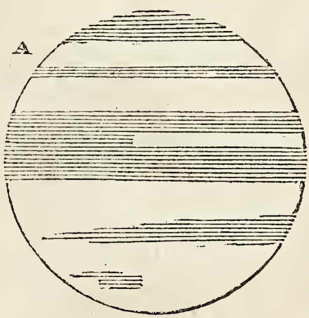
Phosphorus, when used internally, is poisonous, even in so small a quantity as one fourth of a grain.

* See note, page 104.

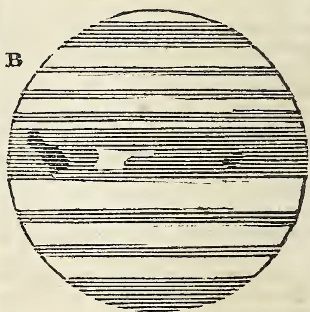
ASTRONOMY.

It has already been remarked, at page 109, that the planet Jupiter is surrounded with broad parallel belts. These belts are variable, both in number and position. The following figures, A and B, exhibit the appearance of Jupiter, according to Sir W. Herschel.

A



B



Different opinions have been entertained by astronomers respecting the cause of these belts. By some they have been regarded as clouds, or as openings in the atmosphere of the planet; while others imagine them to be of a more permanent nature, and to be marks of great physical revolutions, which are perpetually changing the surface of the planet.

The Sun appears to Jupiter only of one twenty-eighth part of the size he does to the Earth: and the light and heat he derives from that Luminary are in the same proportion. But he is in some measure compensated for this want by the quick return of the Sun, occasioned by the prodigiously rapid motion round his axis; and by four satellites, which move round him, at different distances.

These four satellites were discovered by Galileo, an Italian astronomer, in the year 1610. They may be seen by a telescope which magnifies thirty times, and are found to be of great use in determining the longitude of places on the Earth, by their immersions into his shadow, and their emersions out of it.

These satellites are of different magnitudes; the second being the least, the third the greatest, and the fourth the *second* in magnitude. The time which each of these satellites take to go round Jupiter is as follows: The first, or nearest to him, 1d. 18h. 27′ 33″: the second, 3d. 13h. 13 42″; the third, 7d. 3h. 42′ 33″; and the fourth, 16d. 16h. 32′ 8″.

The eclipses of these satellites, by falling into the shadow of Jupiter, have not only been of advantage in enabling astronomers to ascertain the longitude of places, but were the cause of that most curious discovery, made by Roemer, in the year 1675, of the successive propagation of light.

OF SATURN.

The planet Saturn is 79,491 miles in diameter, and performs his revolution round the Sun in 10,746 days, 19 hours, 16 minutes, at the distance of 903,690,197 English miles. His motion in his orbit is said to be 18,000 miles per hour; and the time he revolves on his axis 10h. 16′ by some astronomers, and by others only 6 hours.

Saturn is distinguished from all the other planets, by a large luminous ring surrounding his body, which was discovered by the celebrated Huygens, about the end of the 17th century. The same astronomer also discovered the fourth satellite, which attends this planet, and on that account is sometimes called the Huygenian satellite. The ring which surrounds Saturn appears double when seen through a good telescope, and is seen to cast a deep shadow on the planet. Dr. Herschel is of opinion that the ring has a motion round its axis; but this is doubted by Schroeter, and some other astronomers. Respecting the formation of this strange phenomenon, astronomers have been very different in their opinions: but the difficulty still remains as formidable as ever.

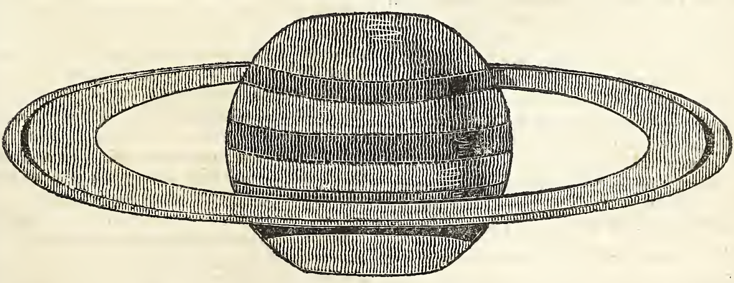
The annexed figure represents this planet as seen by Sir William Herschel, on various occasions, with his powerful telescope.

To Saturn the Sun appears only one-ninetieth part of the size it does to the Earth; and the light and heat which that planet receives from the Sun are in the same proportion. But to compensate for the scantiness of light derived from the Sun, Saturn has been observed to have no fewer than seven satellites revolving round him, besides the luminous ring that surrounds his body. The Huygenian, or fourth satellite, was the first discovered; the first, second, third, and fifth were some years afterwards discovered by Cassini; and the sixth and seventh were discovered by Dr. Herschel, in the year 1789. These satellites are all so small, and at such a distance from the Earth, that they cannot be seen, unless with very powerful telescopes.

The orbit of the planet Saturn was long considered as the boundary of the solar system, except the cometary orbits, which were always believed to stretch far beyond it. But by the discovery of the planet Georgium Sidus, this system has been extended far beyond the limits formerly assigned it.

OF GEORGIUM SIDUS.

A new planet was discovered by Dr. Herschel, on the 13th of March, 1781, and called by him Georgium Sidus, out of respect to his Majesty George III., but astronomers have given it the names of Herschel and Uranus. This planet is situated far beyond the orbit of Saturn, being at the immense distance of 1,822,568,000 miles from the sun. The time it requires to perform its revolution round that luminary is 83 years, 150 days, 18 hours. Its diameter is about 4½ times greater than that of the



earth, or nearly 35,000 English miles. The distance of this planet from the sun being about double that of Saturn, can scarcely be discovered by the naked eye. However, when the sky is very clear, it may be perceived by a good eye like a faint star of the fifth magnitude; but it cannot be readily distinguished from a fixed star with a telescope of a less magnifying power than 200. This planet is placed at so great a distance from the sun, that it can receive but a very small portion of his light: however, this want is in some measure supplied by six satellites that revolve round it, all of which were discovered by Dr. Herschel. The periodic times of these satellites are as follows:—the first, is 5d. 21h. 25′; the second, 8d. 17h. 1′ 19″; the third, 10d. 23h. 4′; the fourth, 13d. 11h. 5′; the fifth, 38d. 1h. 49′; and, the sixth, 107d. 16h. 40′. It is a remarkable circumstance that all these satellites move round the planet in a retrograde order, and that their orbits are nearly all in the same plane, almost perpendicular to the ecliptic.

Miscellaneous Subjects.

CAPTAIN KATER'S METHOD OF DETERMINING THE LENGTH OF THE PENDULUM.

The celebrated Huygens, who is allowed to be the original author of the *Theory* of the Pendulum, had demonstrated, that the centres of *suspension* and *oscillation are convertible* with one another; or that if in any pendulum* the centre of oscillation be made the centre of suspension, the time of vibration will be in both cases the same.

From the consideration of this proposition, Captain Kater discovered that its *converse* must also be true; namely, that if the same pendulum can be made to vibrate in the same time with two different points of suspension, one of these points must be the centre of *oscillation*, when the other is the centre of suspension; and thus their distance, or the *true length* of the Pendulum, is found.†

To reduce this principle to practice, Captain Kater formed a pendulum of a bar of plate brass, one inch and a half wide, and one-eighth of an inch thick. Through this bar two triangular holes are made at the distance of 39·4 inches from each other, to admit the knife edges that are to serve for the axes of suspension in the two opposite positions of the pendulum. Four strong knees of hammered brass, of the same width with the bar, six inches long, and three-fourths of an inch thick, are firmly screwed by pairs to each end of the bar; so that when the knife edges are passed through the triangular apertures, their backs may bear steadily against the perfectly plane surface of the brass knees, which are formed as nearly as possible at right angles to the bar. The bar is cut of such a length that its ends fall short of the extremities of the knee-pieces about two inches.

Two slips of deal, 17 inches long, are inserted at either end, in the spaces thus left between the knee pieces unoccupied by the bar, and are firmly secured by screws. These slips of deal are only half the width of the bar; they are stained black, and a small whalebone point inserted at each end indicates the extent of the arc of vibration.

A cylindrical weight of brass, three inches and a half in diameter, and weighing about two pounds seven ounces, has a rectangular opening in the direction of its diameter, to admit the knee-pieces of one end of the pendulum. This weight, being passed on the pendulum, is so firmly screwed in its place, as to render any change impossible. It is not between the knife edges, but is very near to one of them.

A second weight, of about seven ounces and a half, is made to slide on the bar, near the knife edges, at the opposite end; and it may be fixed at any point on the bar by two screws with which it is furnished. A third weight, or slider, of only four ounces, is moveable along the bar, and is capable of nice adjustment, by means of a screw and a clasp. It is intended to move near the centre of the bar, and has an opening, through which may be seen divisions of the twentieth of an inch engraved on the bar.

It is by means of this moveable weight that the direction of the vibrations in the two opposite positions of the pendulum are adjusted to one another, after which it is secured immoveably in its place.

The knife edges, or prisms, which make so important a part of this apparatus, and are to serve alternately as the axes of motion, are made of the steel prepared in India, and known by the name of *wootz*. The two planes which form the edge of each prism are inclined to one another nearly at an angle of 120 degrees. The edges are as true, or straight, as it was possible to make them, and the hardest temper was given to the steel; and the long series of experiments which have been made with the pendulum proves that they have fully answered the purpose.

As the method adopted by Captain Kater, for determining the number of vibrations of his pendulum in twenty-four hours, was very ingenious, we shall give a short account of it previous to concluding our description of this interesting and delicate apparatus.

It is almost needless to remark, that this pendulum was not intended to be applied to a clock, nor to receive its motion from any thing but its own weight.

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* This word strictly applies to a compound pendulum, and signifies that point in it which is at such a distance from the point of suspension as is equal to a simple pendulum, which vibrates in the same time with the compound one.

† Notwithstanding the simplicity of this well-known proposition, it appears that Captain Kater, was the first person who applied it to the purpose of determining the length of the pendulum.

After the pendulum was accurately suspended, it was placed in front of one of Mr. Arnold's best clocks, and close to it, so that it appeared to pass over the centre of the dial plate, with its extremity reaching a little below the ball of the pendulum. A circular white disk was painted on a piece of black paper, which was attached to the ball of the pendulum clock, and was of such a size, that, when all was at rest, it was just hid from an observer on the opposite side of the room by one of the slips of deal which form the extremities of the brass pendulum. On the opposite side of the room was fixed a wooden stand, as high as the ball of the pendulum of the clock, serving to support a small telescope, magnifying about four times. A diaphragm in the focus was so adjusted as exactly to take in the white disk, and the diameter of the slip of deal which covered it. "Supposing, now," says the ingenious inventor, "both pendulums set in motion, the brass pendulum a little preceding the clock, the slip of deal will first pass through the field of view at each vibration, and will be followed by the white disk. But the brass pendulum being rather the longer of the two, the pendulum of the clock will gain upon it: the white disk will gradually approach the slip of deal, and, at length, at a certain vibration, will be wholly concealed by it. The instant of this total disappearance must be noted. The pendulums will now appear to separate; and, after a certain time, will again approach each other, when the same phenomenon will take place. The interval between the two coincidences will give the number of vibrations made by the pendulum of the clock; the number of vibrations of the brass pendulum is greater by two."

Thus was determined the number of vibrations made by the brass pendulum in a given interval of time; and so, by proportion, the number for a whole day. The interval between the nearest coincidences was about 132½ seconds; and four of these, that is, five successive coincidences, gave an interval of 530 seconds, or 8 minutes 50 seconds; after which the arc described by the brass pendulum became too small. The pendulum was then stopped, and put in motion anew as oft as it was judged proper to repeat the observations.

Being thus enabled to determine, with great accuracy, the number of vibrations performed by his pendulum in a given time, Captain Kater proceeded, by reversing it, to make the vibrations equal in its two oppositions. The sliding weight above mentioned was used for producing this equality, which, after a series of most accurate and careful experiments, was brought about with a degree of precision that could hardly have been anticipated. By the means of twelve sets of experiments, each consisting of a great number of individual trials, with the same end of the pendulum upwards, the number of vibrations in 24 hours was 86058·71; and, with the same end lowest, the mean of as many others gave 86058·72, differing from the former only by the hundredth part of a vibration. The greatest difference was ·43, or less than a half,—a degree of exactness which was never before attained.

From a mean of the twelve sets of experiments here stated, the length of the *second's pendulum* comes out 39·13829 inches, after making every allowance for temperature, buoyancy of the atmosphere, &c., or to 39·1386, reducing it to the level of the sea.

These experiments were made in the house of Mr. Brown, Portland-place, the latitude of which was found to be 51° 31′ 8·4″.

Thus, for the first time, after having been an occasional object of research for more than 160 years, has the centre of oscillation of a compound pendulum been found by experiment alone, according to a method of universal application, and admitting of mathematical precision.

ON THE CHINESE YEAR.

A paper by J. F. Davis, F. R. S. was lately read before the Royal Society of London, on the subject of astronomy, among the Chinese, in which he attempts to show the folly of attributing any thing original in astronomical science to the Chinese, who were entirely ignorant of its objects and principles, before its introduction into their empire by the Arabians, and afterwards by the European missionaries. On this one subject, says the author, that singular nation has deviated from its established prejudices and maxims, against introducing what is foreign,—they have even adopted the errors of the European astronomy, for he discovered in a Chinese book, the exact representation of the Ptolemaic system,—he adds, indeed, it is impossible not to smile at the idea of attributing any science to a people whose learned books are filled with such trumpery as the diagrams of Fo-hi, and a hundred other puerilities of the same kind. Mr. Davis offers several other proofs of the talent which the Chinese possess of stealing the discoveries of other nations and appropriating them to themselves.

The author proceeds to show, that the Chinese have no solar year, but that their year is, in fact, a *lunar year*, consisting of twelve months, of twenty-nine and thirty days alternately, with the triennial intercalation of a thirteenth month, to make it correspond more nearly with the sun's course.

ON THE VELOCITY OF SOUND.

A paper by Dr. Gregory was lately read before the Royal Society of Edinburgh, containing an account of some experiments, made in order to determine the velocity with which sound is transmitted through the atmosphere. Some of the results of these experiments are the following:—

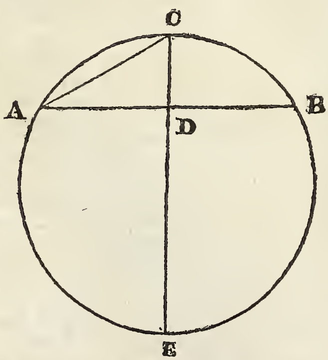
That wind greatly affects sound in point of *intensity*, and, that it affects it also in point of velocity;—that when the direction of the wind *concurs* with that of the sound, the *sum* of their separate velocities gives the *apparent* velocity of sound; when the direction of the wind *opposes* that of the sound, the *difference* of the separate velocities must be taken;—that in the case of echoes, the velocity of the *reflected* sound is the same as that of the *direct* sound, that, therefore, distances may frequently be measured by means of echoes; — that an augmentation of temperature occasions an augmentation of the velocity of sound, and *vice versa*.

Dr. Gregory mentions in a postscript, that it appears from experiments made by Mr. Goldingham, at Madras, that the velocity of sound is different in different climates; and that hygrometric changes are not without their influence.

SOLUTIONS OF QUESTIONS.

Quest. 12, answered by Mr. R. Graham (*the proposer*).

Put $x = AD$, $a = 4$ (DC), $b = 100$ (ACB).



Then by 1 and 47 Euc. $\sqrt{a^2+x} = AC$ and $\frac{8\sqrt{a^2+x^2}-2x}{3} = b$, (see Bonnycastle's Mensuration.) Then by transposing, and squaring both sides, we have $x^2 - \frac{bx}{5} = \frac{9b^2-64a^2}{60}$, and by completing the square and extracting the root, we obtain $x = 49{\cdot}786 = AD$: then by the property of the circle AD^2 $(49{\cdot}786) \div CD$ $(4) = 619{\cdot}661 = DE$, to which add CD (4) and we obtain $CE = 623{\cdot}661$ the *diameter* of the circle required.

Quest. 16, answered by Mr. J. M. Edney.

Put $x =$ the side of the triangle; and $a = {\cdot}4330127$ the area of an equilateral triangle, whose side is unity or 1. Then will $x^2 a =$ the area of the triangle: and from the question arises the following equation $x^2 a = 3x$; whence x is found to be $= \frac{3}{a}$, or $\frac{3}{{\cdot}4330127} = 6{\cdot}9282$ feet, yds. &c, which must be the length of the *side* to answer the condition of the question. And $(6{\cdot}9282)^2 \times {\cdot}4330127 = 6{\cdot}9282 \times 3 = 20{\cdot}7846 =$ the area of the triangle, and also the sum of its sides.

QUESTIONS FOR SOLUTION.

To the Editor of the Artisan.

SIR,

Allow me to lay before your mathematical correspondents the following question for solution (should it meet your approbation), which will oblige, yours, &c.

2, *St. John Street, Clerkenwell.* J. M. EDNEY.

Quest. 17. The dimensions of a block of *Lignum-vitæ* are as follows: the ends are squares, each side of the greater square being $1\frac{1}{4}$ foot, and of the less $\frac{1}{2}$ a foot; the length being 24 feet; required its weight in avoirdupoise ounces?

To the Editor [of th]e Artisan.

SIR,

By inserting the following question in one of the succeeding numbers of the ARTISAN, you will greatly oblige your very humble servant,

Holloway, Exeter. C. A. WILLIAMS.

Quest. 18. If 360 shillings be formed into a circle, so that they may all touch each other, and the points of contact be distant $\frac{3}{4}$ of an inch; what will be the area of a circle passing through all the points of contact?

To the Editor of the Artisan.

SIR,

As you had the kindness to insert my last geometrical question (No. 14.), I have taken the liberty of sending you another, which I will thank you to insert as soon as convenient, which will oblige, yours, &c.

Edinburgh, 4th May, 1824. AN ENGINEER.

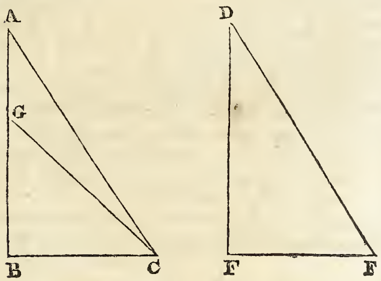
Quest. 19. From two given points, to draw straight lines, making equal angles at the same point in a straight line given in position.

GEOMETRY.

PROPOSITION XXVI.

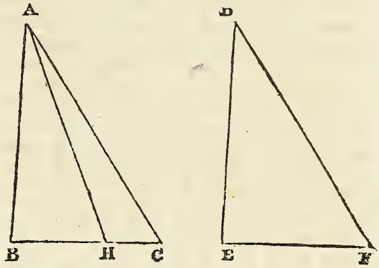
Theorem.—*If two triangles have two angles of the one equal to two angles of the other, each to each; and one side equal to one side, viz. either the sides adjacent to the equal angles, or the sides opposite to the equal angles in each; then shall the other sides be equal, each to each; and also the third angle of the one to the third angle of the other.*

Let A B C, D E F be two triangles which have the angles A B C, B C A equal to the angles D E F, E F D, viz. A B C to D E F, and B C A to E F D; also one side equal to one side; and first let those sides be equal which are adjacent to the angles that are equal in the two triangles, viz. B C to E F; the other sides shall be equal, each to each, viz. A B to D E, and A C to D F; and the third angle B A C to the third angle E D F.



For, if A B be not equal to D E, one of them must be the greater. Let A B be the greater of the two, and make B G equal to D E, and join G C; therefore, because B G is equal to D E, and B C to E F, the two sides G B, B C are equal to the two D E, E F, each to each; and the angle G B C is equal to the angle D E F; therefore the base G C is equal to the base D F, and the triangle G B C to the triangle D E F, and the other angles to the other angles, each to each, to which the equal sides are opposite; therefore the angle G C B is equal to the angle D F E; but D F E is, by the hypothesis, equal to the angle B C A; wherefore also the angle B C G is equal to the angle B C A, the less to the greater, which is impossible; therefore A B is not unequal to D E, that is, it is equal to it; and B C is equal to E F; therefore the two A B, B C are equal to the two D E, E F, each to each; and the angle A B C is equal to the angle D E F; the base therefore A C is equal to the base D F, and the third angle B A C to the third angle E D F.

Next, let the sides which are opposite to the equal angles in each triangle be equal to one another, viz. A B to D E; likewise in this case, the other sides shall be equal, A C to D F, and B C to E F; and also the third angle B A C to the third E D F.



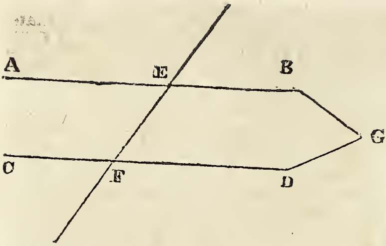
For, if B C be not equal to E F, let B C be the greater of them, and make B H equal to E F, and join A H; and because B H is equal to E F, and A B to D E; the two A B, B H are equal to the two D E, E F, each to each; and they contain equal angles; therefore the base A H is equal to the base D F, and the triangle A B H to the triangle D E F, and the other angles are equal, each to each, to which the equal sides are opposite; therefore the angle B H A is equal to the angle E F D; but E F D is equal to the angle B C A; therefore also the angle B H A is equal to the angle B C A, that is, the exterior angle B H A of the triangle A H C is equal to its interior and opposite angle B C A; which is impossible; wherefore B C is not unequal to E F, that is, it is equal to it; and A B is equal to D E; therefore the two A B, B C, are equal to the two D E, E F, each to each; and they contain equal angles; wherefore the base A C is equal to the base D F, and the third angle B A C to the third angle E D F. Therefore, if two triangles, &c. Q. E. D.

It may be necessary to remark respecting this proposition, that the two *equal* sides (viz. one in each triangle) must be similarly situated in the triangles with respect to the equal angles; that is, both must be either *between* the given angles, or *opposite* to *equal* angles, otherwise the triangles will not be equal.

PROPOSITION XXVII.

Theorem.—*If a straight line falling upon two other straight lines makes the alternate angles equal to one another, these two straight lines are parallel.*

Let the straight line E F, which falls upon the two straight lines A B, C D makes the alternate angles A E F, E F D equal to one another; A B is parallel to C D.

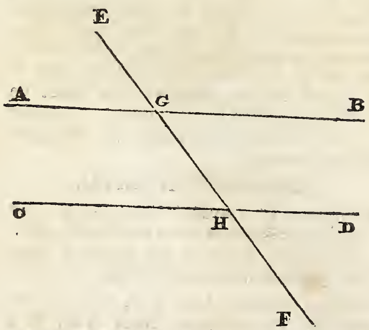


For, if it be not parallel, A B and C D being produced shall meet either towards B, D, or towards A, C; let them be produced and meet towards B, D in the point G; therefore G E F is a triangle, and its exterior angle A E F is greater than the interior and opposite angle E F G; but it is also equal to it, which is impossible; therefore, A B and C D being produced, do not meet towards B, D. In like manner it may be demonstrated, that they do not meet towards A, C; but those straight lines which meet neither way, though produced ever so far, are parallel to one another. A B therefore is parallel to CD. Wherefore, if a straight line, &c. Q. E. D.

PROPOSITION XXVIII.

THEOREM.—*If a straight line falling upon two other straight lines makes the exterior angle equal to the interior and opposite upon the same side of the line; or makes the interior angles upon the same side together equal to two right angles; the two straight lines are parallel to one another.*

Let the straight line E F, which falls upon the two straight lines A B, C D, make the exterior angle E G B equal to the interior and opposite angle G H D upon the same side; or make the interior angles on the same side B G H, G H D together equal to two right angles; A B is parallel to C D.

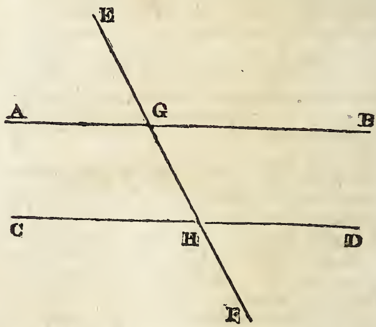


Because the angle E G B is equal to the angle G H D, and the angle E G B equal to the angle A G H, the angle A G H is equal to the angle G H D; and they are the alternate angles; therefore A B is parallel to C D. Again, because the angles B G H, G H D are equal to two right angles; and, that A G H, B G H, are also equal to two right angles; the angles A G H, B G H are equal to the angles B G H, G H D: take away the common angle B G H; therefore the remaining angle A G H is equal to the remaining angle G H D; and they are alternate angles; therefore A B is parallel to C D. Wherefore, if a straight line, &c. Q. E. D.

PROPOSITION XXIX.

THEOREM.—*If a straight line fall upon two parallel straight lines, it makes the alternate angles equal to one another; and the exterior angle equal to the interior and opposite upon the same side; and likewise the two interior angles upon the same side together equal to two right angles*.*

Let the straight line EF fall upon the parallel straight lines A B, C D; the alternate angles A G H, G H D are equal to one another; and the exterior angle E G B is equal to the interior and opposite, upon the same side, G H D; and the two interior angles B G H, G H D upon the same side are together equal to two right angles.



For if A G H be not equal to G H D, one of them must be greater than the other, let A G H be the greater, and because it is greater than the angle G H D, add B G H to each of them; therefore the angles A G H and B G H are greater than the angles B G H and G H D; but the angles A G H and B G H are equal to two right angles; therefore the angles B G H and G H D are less than two right angles, consequently if A B and C D were produced they would meet, but they are parallel by the hypothesis, and therefore would never meet; consequently the angle A G H is not unequal to the angle G H D, that is, it

* These three properties of parallel lines afford the means of determining whether lines are parallel or not.

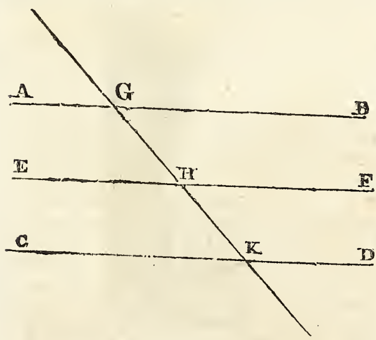
is equal to it. Now, the angle E G B is equal to A G H; and A G H is proved to be equal to G H D; therefore E G B is likewise equal to G H D; add to each of these the angle B G H; therefore the angles E G B, B G H are equal to the angles B G H, G H D; but E G B, B G H are equal to two right angles; therefore also B G H, G H D are equal to two right angles. Wherefore, if a straight line, &c. Q. E. D.

This proposition is the *converse* of the 27th and 28th. It has given Geometers, both ancient and modern, more trouble than all the rest of Euclid's propositions put together; in order to demonstrate it the 12th axiom was assumed; but, that axiom is by no means self evident (see page 17, col. 2); and therefore the 29th proposition, which depends upon it, cannot be said to be proved, unless the axiom itself be previously proved, which cannot easily be done, but by introducing another axiom scarcely less exceptionable than that which was to be demonstrated. This axiom is the following. If two straight lines be drawn through the *same point*, they are not *both* parallel to the same straight line. If this axiom be admitted, the 29th proposition may be demonstrated without the aid of the 12th axiom; but this we shall omit here.

PROPOSITION XXX.

Theorem.—*Straight lines which are parallel to the same straight line, are parallel to one another.*

Let A B, C D be each of them parallel to E F; A B is also parallel to C D.

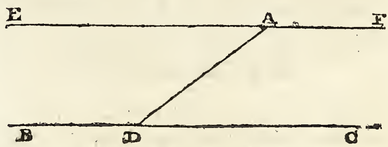


Let the straight line G H K cut A B, E F, C D; and because G H K cuts the parallel straight lines A B, E F, the angle A G H is equal to the angle G H F. Again, because the straight line G K cuts the parallel straight lines E F, C D, the angle G H F is equal to the angle G K D; and it was shown that the angle A G K is equal to the angle G H F; therefore also A G K is equal to G K D; and they are alternate angles; therefore A B is parallel to C D. Wherefore straight lines, &c. Q. E. D.

PROPOSITION XXXI.

Problem.—*To draw a straight line through a given point parallel to a given straight line.*

Let A be the given point, and B C the given straight line; it is required to draw a straight line through the point A, parallel to the straight line B C.



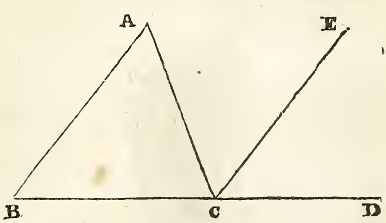
In B C take any point D, and join A D; and at the point A, in the straight line A D, make the angle D A E equal to the angle A D C; and produce the straight line E A to F.

Because the straight line A D, which meets the two straight lines B C, E F, makes the alternate angles E A D, A D C equal to one another, E F is parallel to B C. Therefore the straight line E A F is drawn through the given point A parallel to the given straight line B C. Which was to be done.

PROPOSITION XXXII.

Theorem.—*If a side of any triangle be produced, the exterior angle is equal to the two interior and opposite angles; and the three interior angles of every triangle are equal to two right angles.*

Let A B C be a triangle, and let one of its sides B C be produced to D; the exterior angle A C D is equal to the two interior and opposite angles C A B, A B C; and the three interior angles of the triangle; viz. A B C, B C A, C A B, are together equal to two right angles.



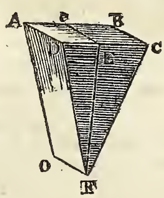
Through the point C draw C E parallel to the straight line A B; and because A B is parallel to C E and A C meets them, the alternate angles B A C A C E are equal.

Again, because A B is parallel to C E, and B D falls upon them, the exterior angle E C D is equal to the interior and opposite angle A B C; but the angle A C E was shown to be equal to the angle B A C; therefore the whole exterior angle A C D is equal to the two interior and opposite angles C A B, A B C; to these angles add the angle A B C, and the angles A C D, A C B are equal to the three angles C B A, B A C, A C B; but the angles A C D, A C B are equal to two right angles; therefore also the angles C B A, B A C, A C B are equal to two right angles. Wherefore, if a side of a triangle, &c. Q. E. D.

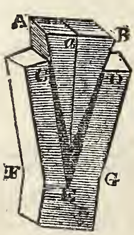
MECHANICS

OF THE WEDGE.

The *wedge* is a triangular prism, made of wood or metal. It is usual to make it *isosceles*, that is, with its opposite sides, or faces, equal. It is, however, sometimes made rectangular, with one of the planes or faces, containing the right angle, placed horizontally. In this case the wedge coincides with the inclined plane. When it is isosceles it may be considered as two equally inclined planes, D E F and C E F, joined together at their bases *e* E F:



then, D C is the whole thickness of the wedge at its back A B C D, where the power is applied: E F is the depth or heighth of the wedge: D F the length of one of its sides, equal to C F the length of the other side; and O F is its sharp edge, which is entered into the wood intended to be split by the force of a hammer or mallet striking perpendicularly on its back. Thus A B is a wedge



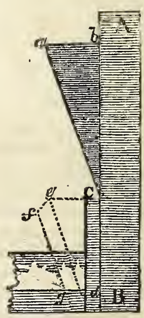
driven into the cleft C D E of the wood F G.

When the wood does not cleave at any distance before the wedge, there will be an equilibrium between the power impelling the wedge downward, and the resistance of the wood acting against the two sides of the wedge; if the power be to the resistance, as half the thickness of the wedge at its back is to the length of either of its sides; that is, as A *a* to A *b*, or B *a* to B *b*. And if the power be increased, so as to overcome the friction of the wedge and the resistance arising from the cohesion of the wood, the wedge will be driven in, and the wood split asunder.

But, when the wood cleaves at any distance before the wedge (as it generally does) the power impelling the wedge will not be to the resistance of the wood, as half the thickness of the wedge is to the length of one of its sides; but as half its thickness is to the length of either side of the *cleft*, estimated from the top or acting part of the wedge. For, if we suppose the wedge to be lengthened down from *b* to the bottom of the cleft at E, the same proportion will hold; namely, that the power will be to the resistance, as half the thickness of the wedge is to the length of either of its sides: or, which amounts to the same thing, as the whole thickness of the wedge is to the length of both its sides.

If one of the resisting bodies only is moveable, the power will be to the resistance as the base of the wedge to its length.

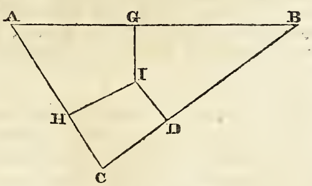
In order to prove what is here advanced concerning the wedge, let us suppose the wedge to be divided lengthwise into two equal parts; and then it will become two equally inclined planes; one of which, as *a b c*,



may be made use of as a half wedge for separating the moulding *e d* from the wainscot A B. It is evident, that when this half wedge has been driven its whole length *a c* between the wainscot and moulding, its side *a c* will be at *e d;* and the moulding will be separated to *f g* from the wainscot. Now, from what has been already proved of the inclined plane, it appears, that to have an equilibrium between the power impelling the half wedge, and the resistance of the moulding, the former must be to the latter, as *a b* to *a c*; that is, as the thickness of the back which receives the stroke is to the length of the side against which the moulding acts. Therefore, since the power upon the half wedge is to the resistance against its side, as the half back *a b* is to the whole side *a c*, it is plain, that the power upon the whole wedge, must be to the resistance against both its sides, as the thickness of the whole back is to the length of both the sides; or as the thickness of the whole back to the length of both sides of the cleft, when the wood splits at any distance before the wedge. For, when the wedge is driven quite into the wood, and the wood splits at ever so small a distance before its edge, the top of the wedge then becomes the acting part, because the wood does not touch it any where else. And since the bottom of the cleft must be considered as that part where the whole cohesion or resistance is accumulated, it is plain, from the nature of the lever, that the farther the power acts from the resistance, the greater is the advantage*.

If the wedge be of a *scalene* form, that is, all its sides unequal, and have forces acting perpendicularly on its sides which keep each other in equilibrio, they are proportional to those sides.

Thus let G I, H I, and D I, the direction of the forces, meet in the point I;



then since the forces keep each other at rest they are proportional to the three sides of a triangle, which are respectively perpendicular to those directions; that is, to the three sides of the wedge.

If the lines of direction, passing through the points of impact, do not meet in a point, the wedge will have a rotatory motion communicated to it; and this motion will be round the centre of gravity of the wedge.

When the directions of the forces are not perpendicular to the sides of the wedge, the effective parts of the forces must be determined by the resolution of forces, (see page 24,) and there will be an equilibrium when those parts are to each other as the sides of the wedge.

A wedge may have the form of a *pyramid*, as well as of a prism; but if the wedge be of a pyramidal form, the forces that act upon it must be resolved according to three axes, by which three equations will be obtained: it is therefore more difficult to determine the effect of the forces on this form of the wedge, than when it is in the form of a prism.

In practice it is the custom to use very small wedges at first, with small angles, and when they are sunk in the body to be cleft, larger wedges with larger angles are successively applied till the purpose is accomplished.

Piercing instruments are all reducible to wedges of this kind, nails, bayonets, stakes, piles, &c. The resistance in some of these increases with the surface to which it is applied.

The common wedge is generally employed for cleaving, and otherwise overcoming the force of cohesion in bodies: it may sometimes be used with advantage for raising great weights to a small height.

All cutting instruments may be referred to it, knives, chissels, scissars, the teeth of animals, &c. A saw is a series of wedges, on which the motion impressed is oblique to the resistance. A wimble is a wedge to which a circular motion is given.

The power applied to the wedge, when great resistance is to be overcome, is usually percussion; and almost the only instance in which it is used for the purpose of equilibrium, is in the construction of *arches*, built of truncated wedges. But as the consideration of this equilibrium would lead to too long a digression in this place, we shall consider the subject in another part of this work.

OF THE SCREW.

The *screw* is a spiral groove or thread, winding round a cylinder, so as to cut all the lines drawn on its surface parallel to its axis, at the same angle. If the spiral is formed on the outside of the cylinder, it is called the *exterior* or *male* screw; and if formed in the inside, it is called the *interior* or *female* screw.

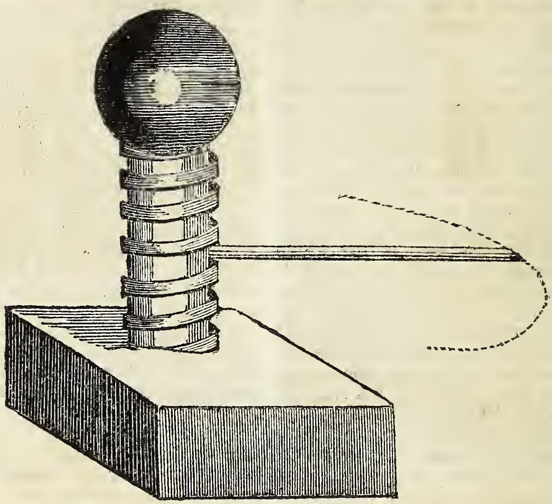
In the former the *spiral* is raised on the surface of a cylinder; and in the latter it is cut out of the inside of a hollow cylinder.*

In considering the screw as a mechanical power, we must regard the male screw as fixed, and carrying or moving a female screw, which constitutes the weight or resistance when it acts by its own gravity, or carries a load.

* There has been a considerable difference among writers on mechanics respecting the rules for determining the power of the wedge. But this has arisen from not attending sufficiently to the direction of the resistance, and to another circumstance, namely, whether both the resisting bodies are moveable, or *one* of them only moveable.

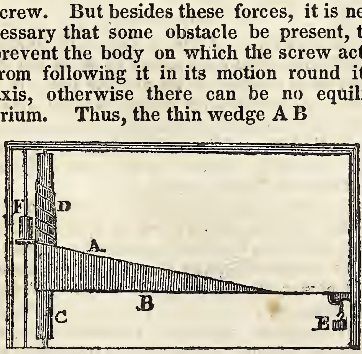
* One turn of the spiral round the cylinder, is usually called a *thread* of the screw.

A lever is generally inserted in a hole in the male screw, and the power is applied to the end of the lever, as represented by the following figure.*



The action of a screw depends on the same principles as that of an inclined plane; for by rolling a thin and flexible wedge, for instance, a triangular piece of card round a cylinder, a screw will be formed.

We may consider the force tending to turn the screw round its axis, as applied horizontally to the base or head of the wedge. The circumference of the cylinder will represent the horizontal length of the wedge, and the distance between the threads will be its height,† consequently the forces required for the equilibrium, are to each other as the height of one thread to the circumference of the screw. But besides these forces, it is necessary that some obstacle be present, to prevent the body on which the screw acts from following it in its motion round its axis, otherwise there can be no equilibrium. Thus, the thin wedge A B



of which the height is one tenth of the length, being rolled round the cylinder C, makes the screw D, by means of which the weight E is capable of supporting a weight ten times as great as F.

If the power applied to the screw, by means of a lever, be parallel to the base, an equilibrium is produced, when the power is to the resistance, as the distance between two threads of the screw, to the circumference of the circle described by the point of the lever to which the power is applied.

Thus, suppose the distance between the threads of a screw to be half an inch, and the length of the lever employed to turn it, to be 24 inches; the circumference of the circle described by this lever will be 151 inches, or 302 half inches; and therefore a force or weight equal to 1 pound acting at the end of the lever, will balance 302 pounds, acting against the screw. Hence it appears, that the longer the lever is, and the nearer the threads are to each other, the greater is the power of the screw.

When a convex and concave, or a male and female screw are fitted to each other, they are sometimes called a screw and nut, as represented by the following figure.

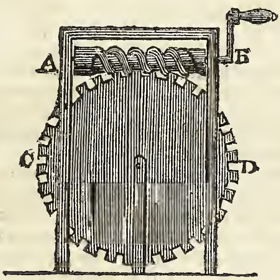
* As the cylinder is turned by a lever, the screw is really a *compound* machine.

† The wedge here alluded to is one in the form of an inclined plane.

The nut acts on the screw with the same mechanical power as a single point would do, since it only divides the pressure amongst the different parts of the spiral.

Sometimes the threads of a screw are made to act on the teeth of a wheel, by which means it has its energy multiplied by their number.

The following is a representation of this application of the screw, which is usually termed the Endless screw.



Here A B is the screw which acts on the teeth of the wheel C D, where a tolerably quick motion of the screw is capable of producing very powerful effects.

The screw is of great use for compressing bodies. A kind of percussion is sometimes added to it, as in the apparatus for coining. The great attrition or friction which takes place in the screw, is useful by retaining it in the state to which it has been once brought, and continuing the effect after the power is removed. The screw is also applied, with much advantage, to raise great weights to a small height, and support them in that situation.

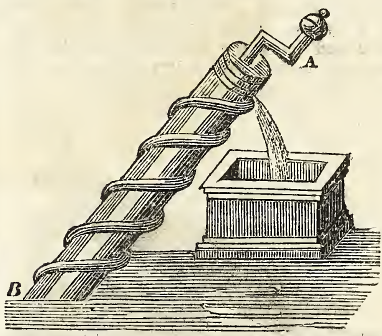
The screw is also employed in the division of mathematical instruments, and the reading off from them. The contrivance known by the name of the micrometer screw, is used for measuring angles with great exactness. In Ramsden's Dividing Instrument, the screw is applied for the same purpose; but we shall treat of these subjects more fully in another part of this work.

HYDRAULICS.

MACHINES FOR RAISING WATER.

Having already treated of the *common sucking pump* under the head of Pneumatics, (see page 133,) we shall here give a description of several ingenious machines used for raising water, which are not so immediately dependent on the action of the *air* for their successful operation.

Among these is the *Screw* of *Archimedes.** This machine consists of a tube, or pipe wound round a cylinder A B in a spiral form, or similar to the threads of a common screw.



The cylinder is inclined to the horizon at an angle of about 45 degrees, and the orifice of the tube B is immersed in water, and when the screw is turned by the handle, the water rises up the spiral and is discharged at A.

This machine is capable, with very little strength, of raising a considerable *quantity* of water; it has, therefore, been found very useful for raising large quantities of water to small heights.

If the water is to be raised to a considerable height, *one screw* will not be sufficient; but this may be effected by a succession of screws: for when the water has been raised by one screw and discharged into an intermediate vessel, it may again be raised to a second vessel by means of another screw; and so on, till it has been raised to the height required.

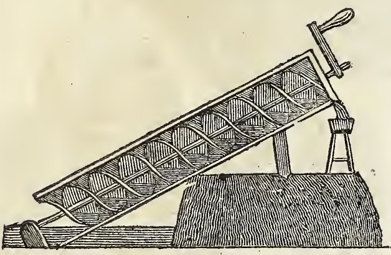
This instrument is sometimes made by fixing a spiral partition round a cylinder, and covering it with an external coating, either of wood or metal; it should be so placed with respect to the surface of the water as to fill in each turn one half of a convolution; for when the orifice remains always immersed, its effect is much diminished.

The spiral is seldom single, but usually

* In Germany this machine is called the *water-snail.*

consists of three or four separate coils, forming a screw which rises slowly round the cylinder. The operation of this machine may be understood by wrapping a cord spirally round a bottle containing a little water, and inclining the bottle at a less angle to the horizon than the inclination of the cord to the axis.* It will then be seen, that if water falls into the lowest part of the spiral when it is at rest, the motion of the bottle about its axis will remove, as it were, the spiral out from below the water, which must therefore occupy the part of the spiral immediately above it; and so on, till the water reaches the top of it.

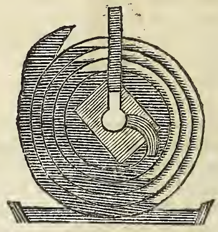
A machine of a similar nature is called by the Germans a *water screw*. It consists of a cylinder with its spiral projections detached from the external cylinder or coating, within which it revolves, as represented by the following figure.



This machine might not improperly be considered as a pump, but its operation is precisely similar to that of the screw of Archimides. It is evident, that some loss must here be occasioned by the want of perfect contact between the screw and its cover; in general, at least one third of the water runs back, and the machine cannot be placed at a greater elevation than 30°; it is also very easily clogged by accidental impurities of the water: yet it has been found to raise more water than the screw of Archimides, when the lower ends of both are immersed to a considerable depth; so, that if the height of the surface of the water to be raised were liable to any great variations, the water screw might be preferable to the screw of Archimides.

These machines are particularly useful when the water to be raised is not pure, but mixed with gravel, weeds, or sand, which could not be raised by ordinary pumps.

The *spiral pump* is a very ingenious machine for raising water. It was invented about the year 1746, by Andrew Wirtz, a pewterer, at Zurich, hence it is sometimes called the *Zurich machine*. It consists of a spiral pipe, either coiled round in one plane, or arranged round the circumference of a cone or cylinder; as represented in the annexed figure.

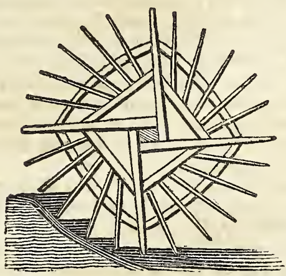


One end of it is connected by a water-tight joint to an ascending pipe, in which the water is to be raised, and the other end receives, during each revolution, nearly equal quantities of air and water. This end of the pipe is furnished with a scoop, or spoon, containing as much water as will fill half a coil, which enters the pipe a little before the spoon has arrived at its highest situation, the other half remaining full of air, which communicates the pressure of the column of water to the preceding portion; and in this manner the effect of nearly all the water in the wheel is united, and becomes equivalent to that of the column of water, or of water mixed with air, in the ascending pipe. The air nearest the joint is compressed into a space much smaller than that which it occupied at its entrance, so that where the height is considerable, it becomes advisable to admit a larger portion of air than would naturally fill half the coil, and this lessens the quantity of water raised, but it lessens also the force required to turn the machine. The joint ought to be conical, in order, that it may be tightened when it becomes loose, and the pressure ought to be removed from it as much as possible. The loss of power, supposing the machine well constructed, arises only from the friction of the water on the pipe, and the friction of the wheel on its axis; and where a large quantity of water is to be raised to a moderate height, both of these resistances may be rendered inconsiderable. But when the height is very great, the length of the spiral must be much increased, so that the weight of the pipe becomes extremely cumbersome, and causes a great friction on the axis, as well as a strain on the machinery: thus, for a height of 40 feet, Dr. Young found, that the wheel required above 100 feet of a pipe which was three quarters of an inch in diameter; and more than one half of the pipe being always full of water, it will be necessary to overcome the friction

† The line, *real* or *imaginary*, round which any body revolves, is called its *axis*.

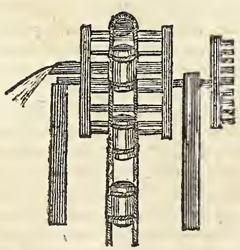
of about 80 feet of such a pipe, which will require 24 times as much excess of pressure to produce a given velocity, as if there were no friction. The centrifugal force of the water in the wheel would also materially impede its ascent if the velocity were considerable, since it would be always possible to turn it so rapidly as to throw the whole water back into the spoon.

Sometimes a *breast-wheel*, which is the reverse of an undershot wheel, is employed as a throwing wheel, either in a vertical or in an inclined position. The following figure represents one of these machines.



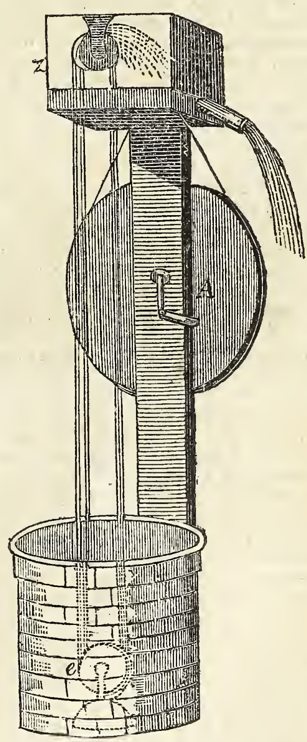
Wheels of this kind are frequently used for draining fens, and are turned by windmills; the float-boards are not placed in the direction which would be best for an undershot wheel, but on the same principle, so as to be perpendicular to the surface when they rise out of it, in order that the water may the more easily flow off from them.

There is another machine for raising water, which consists of a series of earthen pitchers, connected by ropes, and turned by trundles or pinions, over which they pass, which has long been used in Spain, under the name of Auoria, or Noria. In *this* country, buckets of wood are sometimes employed in a similar manner, as in the following figure.



A *bucket wheel* is the reverse of an overshot water-wheel, and the water may be raised by buckets nearly similar to those which are calculated for receiving it in its descent; sometimes the buckets are hung on pins, so as to remain full during the whole ascent; but these wheels are liable to be frequently out of repair. We therefore deem it unnecessary to give a figure of it.

There is another singular machine sometimes used for raising water, called the *rope pump*. It consists of two or three hair ropes passing over a three-grooved pulley *z*, projecting over the well; they also pass under a pulley in the water, and are kept tight by a weight *e*.



The upper pulley is put into swift motion by the wheel A; and the ascending ropes draw up a certain quantity of water by their friction (which is prevented from being scattered by its own cohesion,) and is discharged with great force into the box *z*. The friction of the ropes is aided by the pressure of the atmosphere upon the water which adheres to the ropes.

By a machine of this kind a man can raise eight or nine gallons of water per minute, out of a well 100 feet deep.

Miscellaneous Subjects.

MEMOIR OF M. AGNESI.

Maria Cajetana Agnesi, an Italian lady of great learning, was born at Milan, on the 16th March, 1718. Her inclinations from her earliest youth led her to the study of science, and at an age when young persons of her sex attend only to frivolous pursuits, she had made such astonishing progress in mathematics, that when in 1750 her father, professor in the university at Bologna, was unable to continue his lectures from infirm health, she obtained permission from the pope Benedict XIV. to fill his chair. Before this, at the early age of nineteen, she had supported one hundred and ninety-one theses, which were published in 1738, under the title "Propositiones Philosophicæ." She was also mistress of Latin, Greek, Hebrew, French, German, and Spanish. At length she gave up her studies, and went into the monastery of the Blue Nuns, at Milan, where she died on the 9th of January, 1799. In 1740 she published a discourse tending to prove, "that the study of the liberal arts is not incompatible with the understandings of women." This she had written when scarcely nine years old. Her "Instituzioni Analitche," in 1748, in 2 vols. 4to, were translated in part by Antelmy, with the notes of M. Bossut, under the title of "Traites Elementaires du Calcul differentiel et du Calcul integral," in 1775, in one vol. 8vo. and into English by that eminent judge of mathematical learning, the late Rev. John Colson, M.A. F.R.S. and Lucasion Professor of Mathematics in the university of Cambridge. This learned and ingenious man, who had translated Sir Isaac Newton's Fluxions, with a comment, in 1736, and was well acquainted with what appeared on the same subject, in the course of fourteen years afterward, in the writings of Emerson, Maclaurin, and Simpson, found, after all, the analytical institutions of Agnesi to be so excellent, that he learned the Italian language, at an advanced age, for the sole purpose of translating that work into English, and at his death left the manuscript nearly prepared for the press. In this state it remained for some years, until the late Baron Maseres, with his usual liberal and active spirit, resolved to defray the whole expense of printing a handsome edition, in 2 vols. 4to., which was published in 1801, and was superintended in the press by the Rev. John Hellins, B. D. F. R. S. vicar of Potter's-pury, in Northamptonshire*. Her *eloge* was pronounced by Frisi, and translated into French by Boulard.

* This book is considered by some of our ablest mathematicians as the best work on the application of Algebra to Geometry in the English language.

ARCHITECTURE.

Without entering deeply into the subject of Architecture, we propose to devote a portion of our succeeding pages to the explanation of the general and fundamental principles upon which this highly interesting and beautiful science depends.

The science of Architecture has at all times, and in all civilized countries, been considered not only a pleasing but a highly useful branch of knowledge.

The great utility of this science, and the elegant accomplishments connected with its study, have almost rendered a knowledge of its rules and principles necessary to complete a liberal education. But it is not our intention to bestow encomiums on the science, nor to give any thing like a detailed history of it, but to present our readers with a plain and condensed account of what may be termed its elementary principles.

Architecture is usually divided, with respect to its objects, into three branches, *civil*, military, and naval.

Civil Architecture, called also absolutely, and by way of eminence, *Architecture*, is the art of contriving and executing commodious buildings for the uses of civil life; as houses, temples, theatres, halls, bridges, colleges, porticos, &c.

Architecture is scarcely inferior to any of the arts in point of antiquity.—Nature and necessity taught the first inhabitants of the earth to build themselves huts, tents, and cottages; from which, in course of time, they gradually advanced to more regular and stately habitations, with variety of ornaments, proportions, &c. To what a pitch of magnificence the Tyrians and Egyptians carried *Architecture*, before it came to the Greeks, may be learned from Isaiah xxiii. 8. and from Vitruvius's account of the Egyptian Oeci; their pyramids, obelisks, &c.

Yet, in the common account, *Architecture* should be almost wholly Grecian original: three of the regular orders or manners of building are denominated from them; viz. *Corinthian*, *Ionic*, and *Doric:* and there is scarcely a single member, or moulding, but comes to us with a Greek name.

Be this as it may, it is certain the Romans, from whom we derive it, borrowed what they had entirely from the Greeks; nor do they seem, till then, to have had any other notion of the grandeur and beauty of buildings, beside what arises from their magnitude, strength, &c.—Thus far they were unacquainted with any other beside the *Tuscan*.

Under Augustus, *Architecture* arrived at its glory: Tiberius neglected it, as well as the other polite arts. Nero, amongst a heap of horrible vices, still retained an uncommon passion for building; but luxury and dissoluteness had a greater share in it than true magnificence.—Apollodorus excelled in *Architecture*, under the emperor Trajan, by which he merited the favour of that prince; and it was he who raised the famous Trajan column, subsisting to this day.

After this, *Architecture* began to dwindle again; and though the care and magnificence of Alexander Severus supported it for some time, yet it fell with the western empire, and sunk into a corruption, from whence it was not recovered for the space of twelve centuries.

The ravages of the Visigoths, in the fifth century, destroyed all the most beautiful monuments of antiquity; and *Architecture* thenceforward became so coarse and artless, that their professed architects understood nothing at all of just designing, wherein its whole beauty consists: and hence a new manner of building took its rise, which is called the *Gothic*.

Charlemagne did his utmost to restore *Architecture;* and the French applied themselves to it with success, under the encouragement of H. Capet: his son Robert succeeded him in this design; till by degrees the modern *Architecture* was run into as great an excess of delicacy, as the Gothic had before done into massiveness. To these may be added, the Arabesk and Morisk or Moorish *Architecture*, which were much of a piece with the Gothic, only brought in from the south by the Moors and Saracens, as the former was from the north by the Goths and Vandals.

The architects of the 13th, 14th, and 15th century, who had some knowledge of sculpture, seemed to make perfection consist altogether in the delicacy and multitude of ornaments, which they bestowed on their buildings with a world of care and solicitude, though frequently without judgment or taste.

In the two last centuries, the architects of Italy and France were wholly bent upon retrieving the primitive simplicity and beauty of ancient *Architecture;* in which they did not fail of success: insomuch, that our churches, palaces, &c. are now wholly built after the antique. *Civil Architecture* may be distinguished, with regard to the several periods or states of it, into the antique, ancient, gothic, modern, &c. Another division of *civil Architecture* arises from the different proportions which the different kinds of buildings rendered necessary, that we might have some suitable for every purpose, according to the bulk, strength, delicacy, richness, or simplicity required.

Hence arose five orders, all invented by the ancients at different times, and on different occasions; viz. Tuscan, Doric, Ionic, Corinthian, and Composite. The Gothic Architecture may also be mentioned here, for it is perfectly distinct both from the Grecian and Roman style, although derived from the latter.

[*To be continued.*]

ON THE METHOD OF DETERMINING THE FIGURE OF THE EARTH BY THE PENDULUM.

The method of determining the figure of the earth by means of the *pendulum* depends upon the variation of gravity at the earth's surface.

This subtile and pervading power, tends to communicate to bodies exposed to its influence equal velocities in equal times. One of the modifications of this action is the oscillation of the pendulum, which is of longer or shorter duration, according to the energy of the attractive force, and the square root of the length of the pendulum. If the earth were an exact sphere, destitute of the motion of rotation, and possessing the same density throughout its whole mass, the force of gravity, by which bodies at its surface are drawn towards the centre, would be uniform, and invariable in every latitude. But the elliptical form of the earth destroys this uniformity, and causes the attractive force at the poles to preponderate over that at the equator. This inequality in the force, by which bodies at the surface of the earth retain their positions, is augmented by the diurnal rotation, which, by its centrifugal tendency, impresses a greater disposition on bodies to recede from the centre of the earth at the equator than at the poles, where its effects cease to be felt. By the joint operation of these two causes, one of which acts with a force proportional to the square of the sine of the latitude, a sensible difference ought to be observed in the velocity acquired by heavy bodies, in falling through the same space, as we advance from the equator to the poles. An important relation between the time of the vibration of a pendulum, and that of the descent of a heavy body, according to which the lengths of pendulums, vibrating sychronously, are directly as the force of gravity, enables us to submit this conclusion to the test of experiment. Newton long ago demonstrated, that if the earth were perfectly homogeneous, the same fraction, viz. $\frac{1}{230}$, would express both the compression of the terrestrial ellipsoid, and the increase of gravity from the equator to the poles. This conclusion, which was deduced from the supposition of an uniform density, was afterwards modified, with singular address, by Clairaut, who showed, that the two fractions expressing the compression, and the increase of gravity, though not exactly equal, must always together amount to $\frac{2}{230}$. Assuming the compression, therefore, to be equal to $\frac{1}{312}$, the increase of gravity from the equator to the poles, or the indication of that increase, as given by the length of the pendulum, should be $\frac{2}{230}-\frac{1}{312}$, or $\frac{1}{182}$ nearly. The correctness of this conclusion, if not completely established, is, at least, to a certain extent, confirmed, by the experiments which have been made with the pendulum in different latitudes. La Place having selected fifteen of the best of these observations, and applied to them the necessary corrections, on account of the resistance of the air, difference of temperature, and elevation above the level of the sea, deduced the following results, in which the length of the pendulum at Paris is considered to be unity.

Latitude.	Length of the Seconds Pendulum.	Names of the Observers.	Places of Observation.
Equator	·99669	Bouguer	Peru
9° 32′ 56′	·99689	Ditto	Portobello
11 55 30	·99710	Gentil	Pondicherry
18 0 0	·99745	Campbell	Jamaica
18 27 0	·99728	Bouguer	Petit Grave
34 7 15	·99877	La Caille	Cape G. H.
43 35 45	·99950	Darquier	Toulouse
48 12 48	·99077	Liesganig	Vienna
48 50 0	1·00000	Bouguer	Paris
50 58 0	1·00006	Zach	Gotha
51 30 0	1·00018		London
58 14 53	1·00074	Mallet	Petersburgh
59 56 24	1·00101	Ditto	Ponoi
66 48 0	1·00137	Grischow	Arensberg
67 5 0	1·00148	Mapertius	Tornea

The above results indicate obviously an increase of the force of gravity from the equator towards the poles. La Place has shewn that, in whatever way they are combined, it is impossible to avoid an error of less than ·00018, on the hypothesis of the variation of gravity at the surface of the earth increasing as the squares of the sines of the latitude from the equator to the poles. The expression for the ellipticity, which connects best the different equations of condition, is $\frac{1}{335\cdot78}$, a result which accords in a very remarkable manner with the compression deduced from the measures of the French mathematicians in France, and at the equator.

It may be inferred from these experiments with the pendulum, that the compression of the earth is greater than is compatible with the supposition of an uniform density. The same anomalies, too, which are discernible in the measurement of a degree of the meridian, and which are undoubtedly owing to the dissimilar structure of the globe, may be traced in the results of these experiments. The beautiful property of the pendulum, first discovered by Huggens, that the centre of oscillation and the point of suspension, are interchangeable with each other, and which has been so happily applied by Captain Kater, to determine the length of the seconds' pendulum, (see page 142,) renders this mechanical contrivance infinitely better fitted to ascertain the true figure of the earth, than the complicated methods which were formerly employed for the same purpose. The facility with which the observations may be made, and the certainty of the results with which they are attended, may be expected to furnish much interesting information, not only with respect to the general form of the globe, but also with respect to its structure and composition in particular situations.

ON ATMOSPHERICAL REFRACTION.

A paper on astronomical refraction by Mr. J. Ivory, F. R. S., was lately read before the Royal Society, in which he states that after a long and laborious investigation of this important problem, he has deduced a new table, which is prefixed to the paper. This table is compared with *other* tables which have been long in use, and the characters of which are well established. But Mr. Ivory shows that it is fruitless to expect a near agreement in every single instance, between observation, and any table of refractions whatever; and that there is no test of their accuracy, except the smallness of the *mean* error, in a *series* of observations made at different times.

ON THE CHANGE OF THE PLACE OF THE FIXED STARS.

It appears from a paper by Mr. Pond, Astronomer Royal, lately read before the Royal Society, that he thinks that his observations lead to the conclusion that some variation, either continued or periodical, takes place in the siderial system, which producing but very small deviations in a finite portion of time, has hitherto escaped *notice*. The nature of this motion appears to be such, that the stars are now mostly found a considerable quantity to the *southward* of their computed places. With respect to the *laws* by which these motions are governed, Mr. Pond admits, that his observations are not sufficiently exact to throw any light upon the subject.

REMARKS ON NITRIFICATION, OR THE METHOD OF OBTAINING SALTPETRE.

Of all the numerous arts to which chemical principles are applicable, that of the saltpetre manufacturer suffers the most, from blindly and absurdly following the mere routine of established practice. It would appear that the greater number of individuals employed in it, have no disposition to be enlightened on the subject; neglecting or rejecting the information that has been published by scientific persons, who have turned their attention to the process, they imagine themselves to possess the perfection of the art, in working after the method handed down to them by their predecessors. When they sell their workshops, they sell their mode of practice, which they dignify with the name of their secret, and thus the errors which prevailed in the infancy of the art are perpetuated, and the consumers of the article find endless faults and variations in its manufacture. These considerations recently induced a celebrated chemist to attempt several experiments, with a view to its improvement, both by studying the nature of the earths which contain saltpetre, and that of the substances which are the indispensable agents of the nitrification; and we take the opportunity of laying before our readers the principal results which this gentleman has communicated. He affirms,

1. That air and water only co-operate to produce the nitrification, and that these two agents combined, could never produce it without the presence of vegetable and animal substances in a state of decomposition, which are the fundamental base of it.

2. That calcareous sand, that is which contains lime, and granite washed by spring water, have sometimes presented traces of it. This effect is attributable to the salts which are always found in the water, as well as to the vegetable or animal substances which it always contains, as is shewn by the putrefaction which takes place when it is kept a long time in barrels.

3. That the siliceous or flinty earths are improper for nitrification, and that the calcareous are preferable to the argillaceous or clayey ones.

4. That vegetable and animal particles are the indispensable agents of nitrification; and that the mixture of earths with vegetable decompositions, is less productive than with animal ones.

5. That the dung of woolly animals is preferable in manufacturing saltpetre to that of horses, and the latter to that of cows.

6. That the best method of hastening nitrification, and of obtaining the greatest quantities, is to mix the pure earths with decompositions, partly animal and partly vegetable, in such proportions as experience alone can enable the operator to determine.

ON A NEW PHENOMENON OF ELECTRO-MAGNETISM.

BY SIR HUMPHRY DAVY, BART. PRES. R.S.

This is a contribution of a curious fact to the new and interesting science of electro-magnetism, and it is by such contributions alone, that this infant science can, at present, be expected to make any progress to maturity. Sir H. Davy found, that when two wires were placed in a basin of mercury, perpendicular to the surface, and in the voltaic circuit of a battery with large plates, and the pole of a powerful magnet held either above or below the wires, the mercury immediately began to revolve round the wire as an axis. Masses of mercury, of several inches in diameter, were set in motion, and made to revolve in this manner whenever the pole of the magnet was held near the perpendicular of the wire; but when the pole was held above the mercury, between the two wires, the circular motion ceased, and currents took place in the mercury in opposite directions, one to the right and the other to the left of the magnet. Other circumstances led to the belief that the passage of the electricity produced motions independent of the action of the magnet, and that the appearances were owing to a composition of forces.

The form of the last experiment was inverted, by passing two copper wires through two holes, three inches apart, in the bottom of a glass basin; the basin was then filled with mercury, which stood about the tenth of an inch above the wire. Upon making a communication through this arrangement, with a powerful voltaic circuit, the mercury was immediately seen in violent agitation; its surface became elevated into a small cone above each of the wires; waves flowed off in all directions from these cones, and the only point of rest was apparently where they met in the centre of the mercury, between the two wires. On holding the pole of a powerful magnet at a considerable distance above one of the cones, its apex was diminished and its base extended. At a smaller distance, the surface of the mercury became plane, and rotation slowly began round the wire. As the magnet approached, the rotation became more rapid; and when it was about half an inch above the mercury, a great depression of it was observed above the wire, and a vortex which reached almost to the surface of the wire.

The President thinks, that these phenomena are not produced by any changes of temperature, or by common electrical repulsion, and concludes, that they are of a novel kind.

NAUTICAL EYE-TUBE.

A trial has been made on board the Clio among the Orkneys, and in the Moray Frith by Mr. Adams, of the performance of his eye-tube to the telescope of a sextant for taking altitudes when the horizon is invisible. In making the observations the horizon was always screened from the instrument, and under these circumstances after rejecting a few observations the mean difference of 199 altitudes of the sun, moon, and stars, taken by the eye-tube, from those taken at the same time in the ordinary way by the officers of the Clio, and corrected for dip, amounted to only 1′ 10″. The altitudes taken by the eye-tube are not affected by any dip or depression of the horizon. Considerable care and practice is required in the use of the instrument, but that attained, the latitude, the time at the ship, and consequently the longitude may all be determined by it when the horizon is invisible. By means of it also either the large or the pocket sextant may be employed on shore as a substitute for the theodolite, upon making the necessary allowance for the parallax of the instrument in the name of the index, error, which on becoming sensible, must vary inversely with the distances of the reflected terrestrial objects.

ON THE TEMPERATURE AT CONSIDERABLE DEPTHS OF THE CARIBBEAN SEA.

BY CAPTAIN EDWARD SABINE, F.R.S.

Captain Sabine found the temperature of the water, at a depth of 6000 feet, in latitude 20½ N. and long. 83½ W. near the junction of the Mexican and Caribbean Seas, to be 45°.5, that of the surface being 83°. He infers, that one or two hundred fathoms more line, would have caused the thermometer to descend into water at its maximum of density as depends on heat; this inference being on the presumption that the greatest density of salt water occurs, as is the case in fresh water, at several degrees above its freezing point.

SUPPOSED EFFECT OF MAGNETISM ON CRYSTALLIZATION.

The following is an experiment first made by Professor Maschmann, of Christiana, and confirmed by Professor Hanstein, of the same place. A glass tube is to be bent into a syphon, and placed with the curve downwards, and in the bend is to be placed a small portion of mercury, not sufficient to close the connection between the two legs; a solution of nitrate of silver is then to be introduced, until it rises in both legs of the tube. The precipitation of the mercury in the form of *Arbor Diana* will then take place, slowly only when the syphon is placed in a plane perpendicular to the magnetic meridian; but if it be placed in a plane coinciding with the magnetic meridian, the action is rapid, and the crystallization particularly beautiful, taking place principally in that branch of the syphon towards the *North*. If the syphon be placed in a plane perpendicular to the magnetic meridian, and a strong magnet be brought near it, the precipitation will commence in a short time, and be most copious in that leg of the syphon nearest to the south pole of the magnet.

ACTION OF SULPHUR ON IRON.

Colonel A. Evans has remarked, " that although sulphur has so strong an action on heated wrought iron as immediately to form holes in it, yet it does not at all affect grey cast iron. A plate of wrought iron, ·63 of an inch in thickness, heated to whiteness, and held against a roll of sulphur $\frac{6}{10}$ of an inch in diameter, was in fourteen seconds pierced through with a perfectly cylindrical hole. Another bar about two inches in thickness, was pierced by the same means in fifteen seconds. Good steel was pierced even more rapidly than the iron; but a piece of *grey cast iron*, well scaled and heated till nearly in fusion, was not at all affected by the application of sulphur to its surface, not even a mark being left. A crucible was made of this cast iron, and some iron and sulphur put into it; on applying heat the iron and sulphur soon fused together, but the cast iron underwent no change.

TABLE OF THE FORCE OF STEAM AT DIFFERENT TEMPERATURES.

Temperature.	Force in Inches of Mercury.	Weight in Avoir. lbs.
32°	0	000
42	·08	·039
52	·21	·103
62	·38	·187
72	·58	·285
82	·87	·428
92	1·26	·620
102	1·74	·856
112	2·37	1·166
122	3·16	1·555
132	4·16	2·047
142	5·43	2·673
152	7·00	3·444
162	9·07	4·462
172	11·0	5·412
182	14·9	7·331
192	18·7	9·201
202	23·7	11·662
212	29·8	14·662
222	36·6	18·006
232	44·4	21·844
242	53·6	26·371
252	64·5	31·733
262	77·1	37·932
272	91·7	45·113
282	108·7	53·480
292	128·0	62·975
302	150·0	73·800

The two first columns of the above table were obtained from actual experiment by Mr. Betancourt, and the third we have deduced from the second by calculation. It may, however, be necessary to state, that there are considerable differences between different tables of this kind.

REMARKS ON IRON WIRE SUSPENSION BRIDGES.

The following remarks on this subject are from a memoir by M. Dufour, the engineer of the Geneva bridge.

Speaking of the comparative strength of iron in wires and in bars, M. Dufour says, "The immense advantage of employing iron in wire rather than in bars, is thus rendered evident: it is more manageable, its strength is double, the strength may be better proportioned by putting the number of wires necessary to the resistance required, and a certainty is obtained of the state of the interior parts of the suspending lines, which nothing can give when large bars are used.

"It appears at first that the *minimum* of the force of the wire should be calculated upon, and not the *mean;* but as each brindle contains many wires, although there may be some of a smaller strength, there will be others that will surpass in strength, and thus the mean should be used in estimating the strength of the whole, although in employing a single wire the minimum only ought to be taken."

With respect to the Geneva bridge, M. Dufour says, "that after a period of four months in which the bridge had been in full use, it had not suffered the slightest alteration in its primitive form. The path has retained the degree of curvature given it at first, and no sensible lengthening of the wires has occurred. The bridge, however, has been well tried; curiosity has taken great number of persons on it at once, and all the large stones required in the latter part of the work, were taken over it in carriages without the slightest damage. The elasticity of the bridge is also what it was at first, a man walking with a moderate step does not at all disturb the steadiness of the path; on walking quickly there are slight vibrations produced; but the vibrations are such as never to be communicated from the one bridge to the other, or in any way to affect the masonry. The expense of the bridges was 16,350 francs."

IMPROVEMENT IN LITHOGRAPHIC PRINTING.

An extract from a letter of M. Ridolfi to M. Brugnatelli has just appeared in one of the foreign journals, respecting some improvements in lithographic printing.

It is known, that soap forms an essential part of the ink with which the designs are traced upon the stone. These designs are at first washed with water, acidulated by nitric acid, before they are put under the press, which takes up the excess of the alkali of the soap, and thus renders it insoluble. The stone is then covered for a short time with a solution of gum arabic, which gives it the property of repelling the printing ink more effectually, whilst the roller transmits to it the traits of which the designs are formed.

But the acidulated water, at present in use, not only exerts an action on the soap, the carbonates which constitute the lithographic stones are attacked; and by this means it often happens, that the most delicate parts of the designs are detached from the stone. This particularly happens to compositions, in which there is a considerable difference in the stronger lines, or in the intensity of the tints occasioned by the different lengths of time, or the strength of the acids, necessary to produce the decomposition of the lithographic ink of these lines or shades.

In order to obviate this inconvenience, M. Ridolfi substitutes a weak solution of nitrate of lime in a neutral state, for the acidulated water, which has the property of decomposing the soap, without exercising any action on the stone, and therefore cannot in the smallest degree injure the designs which are traced upon it.

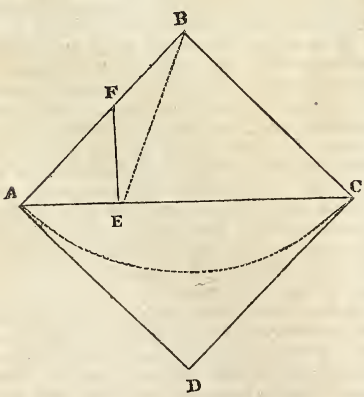
It is however essential, that lithographic designers keep the stones they use perfectly free from unctuous substances, even from the perspiration of the hand, for without this precaution, the stained places give the impression of deep shades.

M. Ridolfi has followed this plan, in his lithographic printing, with success, and forms the nitrate which he uses, by pulverizing broken pieces of the lithographic stones, and throwing them into the aqua fortis of commerce till the effervescence ceases; he dilutes the liquid with rain water, filters it, and then preserves it for use.

SOLUTIONS OF QUESTIONS.

Quest. 14, *answered by* G. G. C.

Let A E be the excess of the diagonal above the side; then draw EF at right angles to A E, and make it equal to A E; join A F, and produce it till F B be equal to F E; from the centre B and distance B A, describe the arc A C, which will intersect the line A E produced in C. Join B C, and draw C D parallel to B A, and A D parallel to B C, and A B C D will be the square required.



Demons. Join B E, then because A E F is a right angle, and A E equal to E F, the angle E A F is half a right angle, Euc. 2 and 9; but A B is equal to B C, and therefore the angle B C A is also half a right angle, Euc. 1 and 5; hence the angle A B C is a right angle, and is therefore equal to the angle F E C; from these equals take away the equal angles F B E and F E B, Euc. 1 and 5, and there remains the angle E B C equal to B E C; hence the side E C is equal to B C, the side of the square; and A C exceeds B C by A E the given excess. Q. E. D.

This question was also solved very ingeniously by J. B. Oldham, although rather circuitously demonstrated.

⊕ has not understood this question.

QUESTIONS FOR SOLUTION.

Quest. 20, *by* Mr. H. Flather, Seymour-place, Bryanstone-square.

What will a chain of standard gold weigh in water when it raises the water an inch, in a square vessel, whose side is 3 inches; and supposing the workmen to have adulterated the said chain with $14\frac{1}{2}$ ounces of silver; how much higher would the water rise upon its immersion in the vessel?

Quest. 21, *by* F. Manchester.

Required the equilibrium power of an overshot water wheel at its circumference as arising from the weight of water only; having the following data.—Diameter of the wheel 24 feet, number of buckets 60, revolutions in a minute 10, feeder of water for driving 1200 hogsheads per hour; the water is thrown into the *third* bucket from the perpendicular, through and about the centre, on the leading side of the wheel and leaves the same 5 buckets before it arrives at the said perpendicular below; the *momentum* of the water being allowed for the friction.

Quest. 22, *by* A. W. a Carpenter.

To trisect a given finite straight line, geometrically, and give the demonstration.

Quest. 23, *by* G. G. C.

Suppose a pendulum that vibrates seconds at the Pole 39·2 inches long; one on the parallel of 45° to be 39·1 inches; and one at the Equator 39 inches: required the force of *gravity* at each of these places?

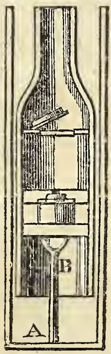
Quest. 24, *by* Mr. J. Tomes.

From two given points on the same side of a line given in position, to draw two lines which shall meet in a point in this line, so that their sum shall be less than the sum of any two lines drawn from the same points, and terminated at any other point in the same line.

PNEUMATICS.

When the height through which water is to be raised, is considerable, some inconvenience might arise from the length of the barrel through which the piston rod of a sucking pump would have to descend, in order that the piston might remain within the limits of atmospheric pressure.

This may, however, be avoided, by placing the moveable valve below the fixed valve, and introducing the piston at the bottom of the barrel, as in the following figure.



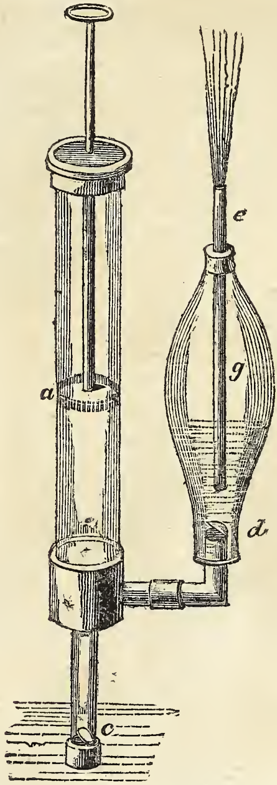
Here the piston rod A B is drawn up by a frame.

Such a machine is called a *lifting pump;* in common with other forcing pumps, it has the disadvantage of thrusting the piston before the rod, and thus tending to bend the rod, and produce an unequal friction in the piston, while in the sucking pump, the principal force always tends to straighten the rod.

The rod of a sucking pump may also be made to work in a collar of leather, and the water may be forced through a valve into an ascending pipe, as in the following figure, which represents a sucking pump converted into a forcing one, by the addition of a collar of leathers at A:

THE FORCING PUMP.

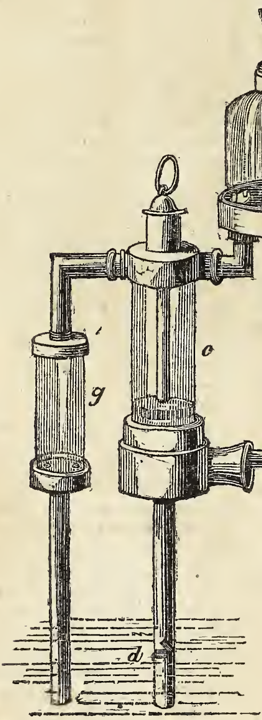
The principle of this pump may be seen in the following model,



where *a* represents a solid piston, sometimes called the plunger, which, when drawn up, rarifies the air below it, and, of course, pressing lighter on the water within the pump than the pressure is on the well, that greater pressure forces up the water through the valve *c*, which (being made a little specifically heavier than the water) sheets, and prevents the return of the water. The piston *a* being now pressed down, the water above *c* is forced through the valve *d* into the air-vessel *g*. This vessel has a pipe *e* screwed tight into its top, that reaches nearly to the bottom of the air-vessel *g*, and is open at both ends: when the water, therefore, covers the lower end of this pipe, the air above it becomes a prisoner and condensed, as the water is forcing in, which by its reaction on the surface of the water, forces that water through the pipe *e* with great velocity, and in a continued jet.

The discharge of water either by sucking or forcing pumps, though naturally intermitting, may be rendered continual by the elasticity of the air condensed in what is called an *air-vessel.*

The following figure represents a pump in which this contrivance is applied.



Here the piston is solid, and when drawn up rarifies the air within the pipe *c*, by which means the water will rise in it, and ascend through the valve *d:* on the descent of the piston, this water will be forced into the air-vessel *e*, and a vacuum will be made above the piston, which, communicating with the pipe *g*, will rarify the air so much within that pipe, that the water will flow up it into the pipe *c*, and cover the piston. This water also will be forced up into the air-vessel, by the ascent, or next stroke of the piston; so that water is raised both by the ascent and descent of the piston.

By applying an air-vessel to the common sucking pump, or to any forcing pump, its motion may be equalized, and its performance improved; for if the orifice of the air-vessel be sufficiently large, the water may be forced into it during the stroke of the pump, with any velocity that may be required, and with little resistance from friction, while the loss of force, from the frequent accelerations and retardations of the whole body of water in a long pipe, must always be considerable.

The condensed air, reacting on the water, expels it more gradually, and in a continual stream, so that the air-vessel has an effect resembling that of a fly-wheel in mechanics.

For *forcing pumps* of all kinds, the common piston, with a collar of loose and elastic leather, (see fig. 4, page 133), is preferable to those of a more complicated structure: the pressure of the water on the inside of the leather makes it sufficienty tight, and the friction is inconsiderable.

In some pumps the leather is omitted, for the sake of simplicity, the loss of water being compensated by the greater durability of the pump; and this loss will be the smaller, in proportion as the motion of the piston is more rapid.

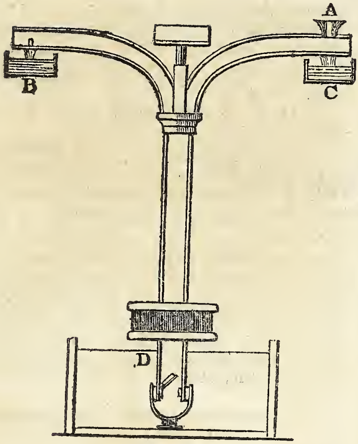
A bag of leather has also been employed for connecting the piston of a pump with the barrel, and in this manner nearly avoiding all friction; but it is probable, that the want of durability would be a great objection to a machine of this kind.

THE CENTRIFUGAL PUMP.

The centrifugal force, which is an impediment to the operation of Wirtz's machine, mentioned at page 152, has sometimes been employed, together with the pressure of the atmosphere, as an immediate agent in raising water, by means of the rotatory pump. This machine consists of a vertical pipe, caused to revolve round its axis, and connected above with a horizontal pipe, which is open at one or at both ends; the whole being furnished with proper valves to prevent the escape of the water when the machine is at rest.

As soon as the rotation becomes sufficiently rapid, the centrifugal force of the water in the horizontal pipe causes it to be discharged at the end, its place being supplied by means of the pressure of the atmosphere on the reservoir below, which forces the water to ascend through the vertical pipe.

As this is one of the most singular methods of raising water, and one that has seldom been tried, we shall here give a representation of the machine, which has been employed for this purpose.



This machine is first filled through the funnel A, and when it is made to revolve with considerable velocity, the water is discharged into a circular trough, of which a section is seen at B and C. The valve at D remains shut while the pump is filling.

A machine of this kind may be so arranged, that, according to theory, little of the force applied may be lost; but it has failed in producing a very advantageous result in practice.

The pipes through which water is raised by pumps of any kind, ought to be as short and as straight as possible; thus, if we had to raise water to a height of 20 feet, and to carry it to a horizontal distance of 100 by means of a forcing pump, it would be more advantageous to raise it, first vertically into a cistern 20 feet above the reservoir, and then let it run along horizontally, or find its level in a bent pipe, than to connect the pump immediately with a single pipe carried to the place of its destination. And for the same reason a sucking pump should be placed as nearly over the well as possible, in order to avoid a loss of force in working it. If very small pipes are used, they will much increase the resistance, by the friction which they occasion.

The various methods of working these pumps, or the different kinds of *power* applied to raise water by them, will be treated of after having described several other forms of pumps, which are not so immediately dependent on the pressure of the atmosphere for their successful operation. This will be done under the head of hydraulics.

OPTICS.

ON THE POLARIZATION OF LIGHT.

This is a new branch of the science of Optics, which sprung up about 14 years ago, from the experiments and ingenuity of M. Malus, Member of the Institute of France; and has since been chiefly cultivated by M. Biot, in France, and by Dr. Brewster, in this country.

The term polarization is employed to express a property, which may be communicated to ordinary light, by virtue of which it exhibits the appearance of having *polarity*, or *poles* possessing different properties.

If a solar ray fall on the anterior surface of an unsilvered mirror plate, making an angle with it of 35° 25′, the ray will be reflected in a right line, so that the angle of reflection will be equal to the angle of incidence. In any point of its reflected path, receive it on another plane of similar glass, it will suffer in general a second partial reflection. But this reflection will vanish, or become null, if the second plate of glass form an angle of 35° 25′ with the first reflected ray, and at the same time be turned, so that the second reflection is made in a plane perpendicular to that in which the first reflection takes place. For the sake of illustration, suppose that the plane of incidence of the ray on the first glass, coincides with the plane of the meridian, and that the reflected ray is vertical. Then, if we make the second inclined plate revolve, it will turn around the reflected ray, forming always with it the same angle; and the plane in which the second reflection takes place, will necessarily be directed towards the different points of the horizon, in different azimuths. This being arranged, the following phenomena will be observed.

When the second plane of reflection is directed in the meridian, and consequently coincides with the first, the intensity of the light reflected by the second glass is at its maximum.

In proportion as the second plane, in its revolution, deviates from its parallelism with the first, the intensity of the reflected light will diminish.

Finally, when the second plane of reflection is placed in the prime vertical, that is east and west, and consequently perpendicular to the first, the intensity of the reflection of light is absolutely null on the two surfaces of the second glass, and the ray is entirely transmitted.

Preserving the second plate at the same inclination to the horizon, if we continue to make it revolve beyond the quadrant now described, the phenomena will be reproduced in the inverse order; that is, the intensity of the light will increase, precisely as it diminished, and it will become equal, at equal distances from the east and west. Hence, when the second plane of reflection returns once more to the meridian, a second maximum of intensity equal to the first recurs.

From these experiments it appears, that the ray reflected by the first glass, is not reflected by the second, under this incidence, when it is presented to it by its east and west sides; but that it is reflected, at least in part, when it is presented to the glass by any two others of its opposite sides. Now if we regard the ray as an infinitely rapid succession of a series of luminous particles, the faces of the ray are merely the successive faces of these particles. We must hence conclude, that these particles possess faces endowed with different physical properties, and that in the present circumstance, the first reflection has turned towards the same sides of space, similar faces, or faces equally endowed at least with the property under consideration. It is this arrangement of its molecules which Malus named the *polarization* of light, assimilating the effect of the first glass to that of a magnetic bar, which would turn a series of magnetic needles, all in the same direction.

Hitherto we have supposed that the ray, whether incident or reflected, formed with the two mirror plates, an angle of 35° 25′; for it is only under this angle that the phenomenon is complete. Without changing the inclination of the ray to the first plate, if we vary never so little the inclination of the second, the intensity of the reflected light is no longer null in any azimuth, but it becomes the feeblest possible in the prime vertical, in which it was formerly null.

Similar phenomena may be produced by substituting for the mirror-glasses, polished plates, formed for the greater part of transparent bodies. The two planes of reflection must always remain rectangular. but they must be presented to the luminous ray, at different angles, according to their nature. Generally, all polished surfaces have the property of thus polarizing, more or less completely, the light which they reflect under certain incidences; but there is for each of them a particular incidence, in which the polarization it impresses is most complete, and for a great many, it amounts to the whole of the reflected light.

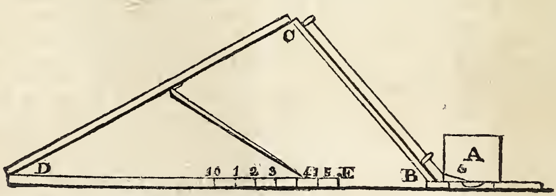
When a ray of light has received polarization in a certain direction, by the processes now described, it carries with it this property into space, preserving it without perceptible alteration, when we make it traverse perpendicularly a considerable mass of air, water, or any substance possessed of single refraction. But the substances which exercise double refraction, in general alter the polarization of the ray, and apparently in a sudden manner, and communicate to it a new polarization of the same nature, but in another direction.

ON THE REFRACTIVE POWER OF DIFFERENT SUBSTANCES.

That a ray of light is refracted, in passing obliquely out of one medium into another of a different density, has already been remarked at page 12 ; but as different substances possess this power in a very different degree, and as the subject is not only curious,but has already been the means of showing much light on the chemical composition of certain bodies, we shall here make a few observations upon it, as well as upon that of double refraction, previous to leaving what may be termed the theoretical part of optics.

The deviation of a ray of light from the rectilineal path for any particular substance depends on the obliquity of the ray to the refracting surface, so that the sine of the angle of refraction is to the angle of incidence in a constant ratio. Sir I. Newton found that unctuous and other inflammable bodies occasioned a greater deviation in the luminous rays than their attractive mass or density gave reason to expect. Hence he conjectured, that both *diamond* and *water* contained some combustible matter, which is now well known to be the case : see page 105.

The ingenious Dr. Wollaston has invented an instrument for measuring the refractive density of substances. This instrument consists of a rectangular prism A of flint glass, under which is attached the substance to be examined.



B C is a rod or ruler 10 inches long, and C D and D E are each 15·83 inches long. When the sights at B and C are so placed, that the divisions between the light and dark portion of the lower surface of the prism is seen through them, the rod F, which carries a *vernier*, shows the index of the refractive density, which in the situation represented in the above figure, is 1·43.

From the refractive power of bodies we may, in many cases, infer their chemical constitution. The purity of essential oils may be pretty correctly inferred by an examination with Dr. Wollaston's instrument.

In oil of cloves for instance, a very material difference may often be discovered.

If this substance be genuine, its refraction power is as high as 1·535, but it is often to be met with as low as 1·493*

Extensive tables of the refractive power of substances are now inserted in some modern works on optics, but our limits will only permit us to insert a very small table of this description.

	Index of Refraction
A vacuum	1·00000
Atmospherical Air	1·00033
Ice	1·30700
Water	1·336
Vitreous humour	1·344
Ether	1·358
Albumen	1·360
Alcohol	1·370
Alum	1·457
Tallow melted	1·460
Borax	1.467
Oil of Olives	1·469
Butter cold	1·480
Linseed oil	1·485
French plate glass	1·500
English ditto	1·504
Gum arabic	1·514
Crown glass, common	1·525
Phosphorus	1·579
Flint-glass	1·586
Iceland Spar, strongest	1·657
Diamond	2·510
Chromate of lead, greatest	2·926

It may be necessary to mention here, that this table exhibits the refractive power of different bodies, without any consideration of their densities or specific gravities; but their absolute refractive powers may be deduced from those given in the table, as follows:

Square the index of the refractive power of any substance, from which subtract 1, then divide the remainder by the specific gravity of the substance, and the quotient will be the absolute refractive power of that substance. This operation is so simple that it is unnecessary to give an example of its application.

* The index of the refractive power of a vacuum is considered the standard of comparison, and is here supposed 1·00000.

OF DOUBLE REFRACTION.

We come now to observe, that in some instances this refraction is *double.*

When a ray of light falls upon glass or water, or even any other fluid, the image formed by refraction is always *single*; when there is a single incident ray, there is only a single refracted ray. These bodies are therefore said to have single refraction. There are, however, various bodies, such as *Iceland spar*, rock crystal, &c. which give two images of any object seen through them, when they are bounded by plane surfaces, or which give two refracted rays when there is only one incident ray.

These bodies are said to have *dauble refraction*, and are called *doubly* refracting *crystals.*

In doubly refracting crystals, one of the images or pencils is refracted according to the law of the *sines*, mentioned at page 12, and is therefore called the *ordinary* ray or image. The second pencil or image is formed according to a new and entirely different law, and is therefore called the *extraordinary* ray or *image.*

In all doubly refracting crystals, there is *one* or more lines along which the *double refraction*, or the separation of the ordinary and extraordinary images, is nothing, or vanishes. This line is called the *axis* of the crystal, or the *axis of double refraction.*

If the extraordinary ray be refracted *towards* the axis of a crystal, that axis is called a *positive* axis of double refraction; but if it be refracted *from* the axis, that axis is called a negative axis of double refraction.

The principle section of a crystal is any plane passing through its axis of double refraction.

All regular crystals which belong to the rhamboidal or pyramidal systems of crystallization, the octahedron and some others, have *one* axis of double refraction, which coincides with the common axis of their crystals.

All regular crystals which belong to the *prismatic* system, or whose primitive forms are the *right prism*, with its base a rectangle, a rhomb or an oblique parallelogram, have two axis of double refraction, coincident with some permanent line in the primitive form of the crystal.

Rules might here be given for determining the law of double refraction in all crystals, whether with *one* or two axis; but as these rules are extremely complicated, we shall now take leave of this subject without inserting them here.

CHEMISTRY.

OF SULPHUR.*

Sulphur is a simple combustible body like the preceding, and the fourth in the order of affinity for oxygen. It is the most easily procured, in a state of purity, of all the simple combustibles, and often found in that state in nature, particularly in the neighbourhood of volcanoes.

It is also procured in large quantities from the mineral substance called *Pyrites*, by distillation.

Sulphur was the first known of all the combustibles, and was long considered as the general cause of combustibility.†

Though very anciently known, sulphur has also been long the source of errors and strange hypotheses in chemistry. It was on this substance, that Stahl founded his theory of phlogiston, which governed the schools for more than a century.

Since the establishment of the pneumatic doctrine, the facts have been accurately observed and much better examined, and the phenomena presented by sulphur have proved, that it has not been decomposed; that it only obeys the laws of composition, and is acted upon in this respect, like phosphorus, carbon, the metals, &c. In general, sulphur has been at all times one of those substances, which have participated the most in the different changes which the science has experienced, and concerning which Philosophers have been more particularly employed.

Sulphur is consequently a body whose combinations are the most numerous, and at present the best understood.

1. Sulphur is a hard brittle substance, commonly of a yellow colour, without any smell, and of a weak though perceptible taste.

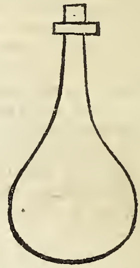
It is a non-conductor of electricity, and of course becomes electric by friction. Its specific gravity is 1·990.

Sulphur undergoes no change by being allowed to remain exposed to the open air. When thrown into water, it does not melt as common salt does, but falls to the bottom, and remains there unchanged: it is therefore insoluble in water.

2. If a considerable piece of sulphur be exposed to a sudden though gentle heat, by holding it in the hand, for instance, it breaks to pieces with a crackling noise.

When sulphur is heated to the temperature of about 170°, it rises up in the form of a fine powder, which may be easily collected in a proper vessel. This powder is called *flowers of sulphur*.* When substances fly off in this manner on the application of a moderate heat, they are called *volatile;* and the process itself, by which they are raised, is called *volatilization.*

When heated to the temperature of about 214° of Fahrenheit's thermometer, it melts and becomes as liquid as water. If this experiment be made in a thin glass vessel, like the following figure, the vessel may



be placed upon burning coals, without much risk of breaking it. The strong heat soon causes the sulphur to boil, and converts it into a brown coloured vapour, which fills the vessel, and issues with considerable force out from its mouth.

3. There are a great many bodies which, after being dissolved in water or melted by heat, are capable of assuming certain regular figures. If a quantity of common salt, for instance, be dissolved in water, and that fluid, by the application of a moderate heat, be made to fly off in the form of steam; or, in other words, if the water be slowly *evaporated,* the salt will fall to the bottom of the vessel in cubes. These regular figures are called *crystals.* Now sulphur is capable of crystallizing. If it be melted, and as soon as its surface begins to congeal, the liquid sulphur beneath be poured out, the internal cavity will exhibit long needle-shaped crystals of an octahedral figure. This method of crystallizing sulphur was contrived by Rouelle. If the experiment be made in a glass vessel, or upon a flat plate of iron, the crystals will be perceived beginning to shoot when the temperature sinks to about 220°.

3. When sulphur is heated to the temperature of 560° in the open air, it takes fire spontaneously, and burns with a pale blue flame, and at the same time emits a great quantity of fumes of a very strong suffocating odour. When set on fire, and then plunged into a jar full of oxygen gas, it burns with a bright violet coloured flame, and at the same time emits a vast

* Sulphur is also known by the name of *brimstone.*

† See page 15.

* It is only in this state that sulphur is to be found in commerce tolerably pure. *Roll sulphur* usually contains a considerable portion of foreign bodies.

quantity of fumes. If the heat be continued long enough, the sulphur burns all away without leaving any ashes or *residuum*. If the fumes be collected, they are found to consist entirely of *sulphuric acid*. By combustion, then, sulphur is converted into an acid.* This fact was known several centuries ago; but no intelligible explanation was given of it till the time of Stahl, who founded the theory already alluded to, upon the experiments he made on this substance.

There are two facts, however, which Stahl either did not know, or did not sufficiently attend to, neither of which was accounted for by his theory. The first is, that sulphur will not burn if air be completely excluded; the second, that sulphuric acid is heavier than the sulphur from which it was produced.

To account for these, or facts similar to these, succeeding chemists refined upon the theory of Stahl, deprived his phlogiston of *gravity*, and even assigned it a principle of *levity*. Still, however, the necessity of the contact of air remained unexplained. At last Mr. Lavoisier, who had already distinguished himself by the extensiveness of his views, the accuracy of his experiments, and the precision of his reasoning, undertook the examination of this subject, and his experiments were published in the Memoirs of the Academy of Sciences for 1777. He put a quantity of sulphur into a large vessel filled with air, which he inverted into another vessel containing mercury, and then set fire to the sulphur by means of a burning glass. It emitted a blue flame, accompanied with thick vapours, but was very soon extinguished, and could not be again kindled. There was, however, a little sulphuric acid formed, which was a good deal heavier than the sulphur which had disappeared; there was also a diminution in the air of the vessel proportional to this increase of weight. The sulphur, therefore, during its conversion into an acid, must have absorbed part of the air. He then put a quantity of sulphuret of iron, which consists of sulphur and iron combined together, into a glass vessel full of air, which he inverted over water.† The quantity of air in the vessel continued diminishing for eighteen days, as was evident from the ascent of the water to occupy the space which it had left; but after that period no further diminution took place. On examining the sulphuret, it was found somewhat heavier than when first introduced into the vessel, and the air of the vessel wanted precisely the same weight. Now this air had lost all its oxygen; consequently the whole of that oxygen must have entered into the sulphuret. Part of the sulphur was converted into sulphuric acid; and as all the rest of the sulphuret was unchanged, the whole of the increase of weight must have been owing to something which had entered into that part of the sulphur which was converted into acid. This something we know was oxygen. Sulphuric acid therefore must be composed of sulphur and oxygen; for as the original weight of the whole contents of the vessel remained exactly the same, there was not the smallest reason to suppose that any substance had left the sulphur.

The combustion of sulphur, then, is nothing else than the act of its combination with oxygen; and for any thing which we know to the contrary, it is a simple substance.

From the slow combustibility of sulphur, and the difficulty of condensing the acid fumes, it was not possible for Lavoisier to ascertain with how much it unites during its combustion in oxygen gas; but it may be converted into sulphuric acid by boiling it in a quantity of *nitric acid:** and the proportion of oxygen with which it has united may be deduced from the increase of its weight. This experiment was first tried by Berthollet, but his apparatus did not enable him to attain precision. Thenard and Chenevix repeated it, and with proper precautions. According to the first, 100 parts of sulphur unite with 80; according to the last, with 62·6 of oxygen; the mean of both gives us 71·3 of oxygen. If we consider it as nearly correct, then 100 grains of sulphur unite, during combustion, with nearly 209 cubic inches of oxygen gas; and one grain of sulphur is capable of depriving 9½ inches of common air of all its oxygen.

4. But sulphur does not always unite with so great a quantity of oxygen: indeed it usually burns with a blue flame, and emits an exceedingly offensive smell. This smell is occasioned by the escape of a gas, which may be confined in proper vessels: it is *sulphurous acid*. By adding oxygen to it we may convert it into sulphuric acid; a proof that it contains less oxygen than that acid.

5. If sulphur be kept melted in an open vessel, it becomes gradually thick and viscid. When in this state, if it be poured into a basin of water, it will be found to be of a red colour, and as soft as wax. In this state it is employed to take off impressions from seals and medals. These casts are known in this country by the

* Acids are a class of compound bodies, which will be afterwards described.

† This experiment was first made by Scheele, but with a different view.

* This acid, called in common language *aqua fortis*, will be described hereafter.

name of *sulphurs*. When exposed to the air for a few days, the sulphur soon recovers its original brittleness, but it retains its red colour. It is supposed at present, that sulphur, rendered viscid and red by a long fusion, has combined with a little oxygen; hence the term *oxide of sulphur* has been applied to it. This substance, when newly made, has a violet colour; it has a fibrous texture; its specific gravity is 2·3; it is tough, and has a straw colour when pounded. Dr. Thomson found that 100 parts of it, when converted into sulphuric acid by means of nitric acid, became 160 parts, and therefore had united with 60 parts of oxygen.

6. When sulphur is first obtained by precipitation from any liquid that holds it in solution, it is always of a white colour, which gradually changes to greenish yellow when the sulphur is exposed to the open air. If this white powder, or *lac sulphuris* as it is called, be exposed to a low heat in a retort, it soon acquires the colour of common sulphur; and, at the same time, a quantity of water is deposited in the beak of the retort. On the other hand, when a little water is dropt into melted sulphur, the portion in contact with the water immediately assumes the white colour of *lac sulphuris*. If common sulphur be sublimed into a vessel filled with the vapour of water, we obtain *lac sulphuris* of the usual whiteness, instead of the common flowers of sulphur. These facts prove that *lac sulphuris* is a compound of sulphur and water. Hence we may conclude, that greenish yellow is the natural colour of sulphur. Whiteness indicates the presence of water.

7. Sulphur unites very readily to hydrogen, and forms a compound known by the name of *sulphuretted hydrogen gas;* but this will be afterwards noticed in treating of the gases.

Till lately it was supposed that sulphur does not combine with *carbon*; but Messrs. Clement and Desormes, two French chemists, have discovered that they may be made to combine; and that when this is the case, the compound assumes the form of a liquid, to which has been given the name of *carburet* of sulphur.

This liquid is transparent, and colourless when pure, but very frequently it has a greenish yellow tinge. Its taste is cooling and pungent, and its odour strong and peculiar. Its specific gravity is 1·35. It does not mix with water. When put into the receiver of an air pump, and the air exhausted, it rises in bubbles through the water, and assumes the form of a gas. The same change takes place when it is introduced to the top of a barometer tube; but it is again condensed into a liquid when the tube is immersed under mercury.

This compound burns easily like spirit of wine and many other liquids. During the combustion it emits a sulphureous odour; sulphur is deposited, and charcoal remains behind. When a little of it is put into a bottle filled with oxygen gas, it gradually mixes with the oxygen, and assumes the gaseous form. If a burning taper be applied to the mouth of the bottle, the mixture burns instantaneously, and with an explosion so violent as to endanger the vessel. It assumes the gaseous form in the same way when placed in contact with air. It does not detonate when kindled, but burns quietly.

This liquid dissolves phosphorus readily. It also dissolves a small portion of sulphur; but has no action whatever on charcoal.

Sulphur combines with phosphorus very readily.

All that is necessary to effect this is to mix the two substances together, and apply a degree of heat sufficient to melt them. The compound has a yellowish white colour, and a crystallized appearance. The combination may also be obtained by heating the mixture in a glass tube, having its mouth properly secured from the air. The sulphuret of phosphorus, thus prepared, is more combustible than phosphorus. If it be set on fire by means of a hot wire, allowed to burn for a little, and then extinguished by excluding the air, the phosphorus, and perhaps the sulphur, is oxidized, and the mixture acquires the property of taking fire spontaneously as soon as it comes in contact with air.

The combination may likewise be effected by putting the two bodies into a retort, or flask, filled with water, and applying heat cautiously and slowly. They combine together gradually as soon as the phosphorus is melted. It is however necessary to apply the heat cautiously, because the sulphuret of phosphorus has the property of decomposing water. The rate of decomposition increases very rapidly with the temperature, a portion of the two combustibles being converted into acids by uniting with the oxygen: the hydrogen at the moment of its evolution unites with sulphur and phosphorus, and forms sulphuretted and phosphuretted gases. This evolution, at the boiling temperature, is so rapid as to occasion violent explosions. The circumstances attending this explosion have been examined, and it has been found that the gas emitted burns spontaneously, and leaves phosphoric and sulphuric acids. The sulphuret of phosphorus formed under *water* has a yellow colour. It gives to the water in which it is kept an acid taste, and the smell of sulphuretted hydrogen. It burns, according to Mr. Briggs, at a temperature considerably lower than a similar compound made in the dry way. This induces him to conclude, that during the combination a little water is decomposed, and the oxygen expended in converting the sulphur and phosphorus into oxides.

This compound was particularly examined by Pelletier, and found to congeal at different temperatures according to the proportion in which the sulphur and phosphorus are combined. When the sulphur predominates, the compound is called *phosphuret* of *sulphur* ; and when the phosphorus predominates, it is called *sulphuret* of *phosphorus*.

ASTRONOMY.

NEW PLANETS.

OF CERES.

The planet Ceres, which is situated between the orbits of Mars and Jupiter, was discovered at Palermo, in Sicily, on the 1st of January, 1801, by M. Piazzi, an ingenious astronomer, who has since distinguished himself by his numerous observations. Ceres is of a ruddy colour, but not deep, and appears about the size of a star of the eighth magnitude. It seems to be surrounded with a large dense atmosphere, and plainly exhibits a disc when examined by a telescope which magnifies about 200 times. Ceres performs her revolution round the sun in 4 years, 7 months, and 10 days, and her mean distance from that luminary is nearly 260,000,000 English miles. The eccentricity of her orbit is a little greater than that of Mercury, and its inclination to the ecliptic exceeds that of all the old planets. The magnitude of this planet is not yet well ascertained. Dr. Herschel makes her diameter only 160 miles, while Schroeter makes it 1624 miles. This great difference, says Schroeter, was occasioned by Herschel observing with his projection-micrometer at too great a distance from the eye, and measuring only the middle clear part of the nucleus.

OF PALLAS.

The planet Pallas was discovered at Bremen, in Lower Saxony, on the 28th of March, 1802, by Dr. Olbers. It is situated between the orbits of Mars and Jupiter, and is nearly of the same magnitude with Ceres. It is of a less ruddy colour than Ceres, and performs its revolution round the run nearly in the same time. The atmosphere of this planet, according to Schroeter, is to that of Ceres in the proportion of 2 to 3. It undergoes similar changes, but the light of the planet exhibits greater variations.

OF JUNO.

The planet Juno, situated between the orbits of Mars and Jupiter, was discovered by M. Harding at the Observatory of Lilienthal, near Bremen, on the evening of the 1st of September, 1804. While M. Harding was forming an atlas of all the stars which were near the orbits of Ceres and Pallas, he observed in the constellation Pisces, a small star of the eighth magnitude, which was not mentioned by La Lande in his *Histoire Celeste*, and being ignorant of its latitude and longitude, he put it down in his chart as nearly as he could estimate with his eye. Two days afterwards the star disappeared; but he perceived another that he had not seen before, resembling the first in size and colour, and situated a little to the south-west of its place. He observed it again on the 5th of September, and finding that it had moved still farther to the south-west, he concluded that it was a planet. It is of a reddish colour, and free from that faint whitish light that surrounds Pallas. Its diameter, and mean distance from the sun, are less than those of Pallas or Ceres.

OF VESTA.

This planet, which appears like a star of the sixth magnitude, of a dusky colour, similar in appearance to Herschel, was discovered on the 29th of March, 1807, by Dr. Olbers, who gave it the name of Vesta. In a clear evening it may be seen by the naked eye. Its light is more intense, pure, and white, than any of the other three new planets. The time it takes to perform its annual revolution is 3 years, 66 days, 4 hours. Its diameter is stated at 238 miles, and its mean distance from the sun at 225,000,000 miles.

OF COMETS.

Of all celestial bodies, Comets have given rise to the greatest number of speculations. In the ages of ignorance and superstition, they were believed to be the harbingers of divine vengeance, and to portend great political and physical convulsions. The most ancient opinion respecting their nature was, that they were enormous meteors formed in the earth's atmosphere. Yet many of the ancients entertained opinions respecting them agreeing with some parts of the *modern* hypothesis respecting these bodies ; for they believed that they were so far of the nature of planets that they had their periodical times of appearing, and that when they were out of sight, they were carried aloft to an immense distance from the earth, but again became visible when they descended into the lower regions of the air, when they were nearer to us. Modern astronomers are now generally agreed that they have no light of their own, and appear luminous only by the light of the sun. They have no visible disc, and shine with a pale whitish light, accompanied with long transparent trains or tails, proceeding from that side which is turned away from the sun. When a comet is viewed through a good telescope, it appears like a mass of vapours surrounding a dark nucleus of different degrees of opacity in different comets. As these bodies approach the sun their light becomes more brilliant, and after they reach their Perihelion often exceed any of the planets in lustre Their tails are also observed to increase both in length and brightness as they approach the sun. The opinions of astronomers respecting these tails have been very different. Tycho Brahe, who was the first that gave the comets their true rank in the creation, supposed that the tail was occasioned by the rays of the sun passing through the nucleus of the comet, which he believed to be transparent. Kepler thought that it was the atmosphere of the comet which was driven behind it by the force of the solar rays. Sir Isaac Newton maintained that the tail was a thin vapour, ascending by means of the sun's heat, as smoke does from the earth. Euler supposes that the tail is produced by the impulse of the solar rays driving off the atmosphere from the comet. Dr. Hamilton, of Dublin, supposes them to be streams of electric matter.

In any of these opinions there is little to entitle it to preference above the others ; and till multiplied observations shall have added to the imperfect knowledge which we at present possess of these bodies, it is perhaps better not to give a decided preference to any of them.

From a number of observations made by Sir Isaac Newton on the comet that appeared in the year 1680, he was enabled to discover the true motion of these bodies.

Dr. Halley, following the theory of Newton, set himself to collect all the observations which had been made on comets, and calculated the elements of 24 of them. By computations founded on these elements, he concluded, that the comet of 1682 was the same that had appeared in the years 1456, 1531, and 1607 ; that it had a period of 75 or 76 years; and he ventured to predict, that it would appear again about the year 1758, which it actually did; therefore it may be expected to appear again in the year 1835.

When a comet makes its appearance, it is only for a very short period, seldom exceeding a few months, and sometimes only a few weeks. Instead of moving from *west* to *east*, like the planets, in orbits making small angles with the ecliptic, they are observed to cross it at all angles. Their progress among the fixed stars is in general more rapid than that of the planets, and their change of apparent magnitude is much more remarkable. When a comet retires from the sun, its tail decreases and nearly resumes its first appearance. Those comets which never approach very near the sun, have nothing but a coma or nebulosity round them during the whole time of their continuance in view.

The tail of a comet is always transparent, for the stars are often distinctly visible through it, and it has even been said, that on some occasions they have been seen through the nucleus or head. The length and form of the tail are very different. Sometimes it extends only a few degrees, at others it extends more than 90 degrees. In the great comet that appeared in the year 1680, the tail subtended an angle of 70°, and the tail of the one which appeared in 1618, an angle of 104°. The tail sometimes consists of diverging streams of light: that of the comet which appeared in the year 1744, consisted of six, all proceeding from the head, and all a little bent in the same direction. The tail of the beautiful comet which appeared in 1811, was composed of two diverging beams of faint light, slightly coloured, which made an angle of 15° to 20°, and sometimes much more. Both of them were a little bent outward ; and the space between them was comparatively obscure.

The apparent difference in the length and lustre of the tail of comets, has given rise to a popular division of these singular bodies into three kinds; viz. *bearded, tailed* and *hairy* comets ; but this division rather relates to the several circumstances of the *same* comet, than to the phenomena of different ones. Thus when the comet is *east* of the sun, and moves *from* him, it is said to be *bearded,* because the light precedes it in the manner of a beard; when the comet is *west* of the sun, and sets after him, it is said to be *tailed,* because the train of light follows it in the manner of a tail ; and when the sun and comet are diametrically opposite, the earth being between them, the train or tail is all hid behind the body of the comet, except the extremities, which being broader than the body of the comet, appear to surround it like a border of *hair,* and on this account it is called hairy. But there have been several comets observed, whose disc was as clear, round, and well defined, as that of Jupiter, without either tail, beard, or coma.

The magnitude of comets has been observed to be very different; many of them without their *coma* have appeared no larger than stars of the first magnitude ; but some authors have given us accounts of others which appeared much greater ; such was the one that appeared in the time of the emperor Nero, which, as Seneca relates, was not inferior, in apparent magnitude, to the sun himself. The comet which Hevelius observed in the year 1652, did not seem to be less than the moon, though it was deficient in splendour, for it had a pale, dim light, and appeared with a dismal aspect. Most comets have dense and dark atmospheres surrounding their bodies, which weaken the sun's rays that fall upon them; but within these appears the nucleus, or solid body of the comet, which, when the sky is clear, will often give a more splendid light.

Respecting the nature of these singular and extraordinary bodies, Philosophers and Astronomers in all ages and countries have been very much divided in their opinions. The vulgar have however invariably considered them as *evil omens*, and forerunners of war, pestilence, famine, &c.; and to adopt the language of an old poet;

"The blazing star was viewed—
Threat'ning the world with famine, plague, and war;
To princes death; to kingdoms many crosses
To all estates inevitable losses;
To herdsmen rot; to ploughmen hapless seasons;
To sailors storms; to cities civil treasons;"

The Chaldeans, who were eminent for their astronomical researches, were of opinion, that comets were lasting bodies, which had stated revolutions as well as the planets, but in orbits considerably more extensive, on which account they are only visible while near the earth, but disappear again when they ascend into the higher regions. Pythagoras taught, that comets were wandering stars, disappearing in the superior parts of their orbits, and becoming visible only in the lower parts of them. Some of the ancient Philosophers supposed, they were nothing else but a reflection of the beams from the sun or moon, and generated as a rainbow; others supposed they arose from vapours and exhalations. The illustrious Aristotle was of opinion they were meteors. Modern philosophers have been equally perplexed as their predecessors in accounting for the nature of these magnificent celestial appearances. The eccentric but learned Paracelsus gravely affirmed, that they were formed and composed by Angels and Spirits to foretel some good or bad events. Kepler, the celebrated Astronomer, asserted that comets were monsters, and generated in the celestial spaces by an animal faculty! The sentiments of Bodin, a learned French writer of the 16th century, were yet more absurd; for he maintained that comets are spirits which have lived upon the earth innumerable ages, and being at last arrived on the confines of death, celebrate their last triumph, or are called to the Firmament like shining stars!

James Bernoulli, a celebrated Swiss philosopher, formed a rational conjecture relative to comets in viewing them as the satellites of some very distant Planets invisible on the earth on account of its distance, as were also the satellites, unless when in a certain part of their course. Tycho Brahe, the illustrious but unfortunate Philosopher of Denmark, supported a true hypothesis on this subject; he averred, that a comet had no sensible diurnal parallax, and therefore was not only far above the regions of our atmosphere, but much higher than the moon; that few have come so near the earth as to have any diurnal parallax, yet all comets have an annual parallax, the revolution of the earth in its orbit, causes their apparent motion to be very different from what it would be, if viewed from the sun, which demonstrates, that they are much nearer than the fixed stars which have no such parallax.

Descartes advanced another opinion: which is, that comets are only stars that were firmly fixed like the rest, but becoming gradually covered with *maculæ* or spots, and at length wholly deprived of their light, cannot keep their places, but are carried off by the vortices* of the circumjacent stars; and in proportion to the magnitude and solidity moved in such a manner, as to be brought nearer to the orb of Saturn; and thus coming within reach of the sun's light, are rendered visible.

The number of comets belonging to the solar system, is said not to be less than 450; but the periods of not more than three of these are known. The velocity of these bodies, and their distance from the sun when in the remotest part of their orbits, exceed all human comprehension. Sir Isaac Newton calculated the velocity of the comet of 1680, and found it to be 880,000 miles per hour, and its aphelion distance not less than 11,200,000,000 miles.

Respecting the use of these bodies, many conjectures have been formed. Mr. Whiston

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* Descartes supposed, that every thing in the Universe was formed from very minute bodies called *Atoms*, which had been floating in open space. To each atom he attributed a motion on its axis; and he also maintained, that there was a general motion of the whole Universe round like a *vortex*, or whirlpool. In the centre of this vortex was the sun with all the planets circulating round him, at different distances; and that each star was also the centre of a general vortex round which its planets turned. Besides these general vortices, each planet had a vortex of its own, by which its satellites (if it had any) were whirled round, and any other body that came within its reach.

thought it probable, that they were appointed by the Almighty as places of punishment for sinners after *death*, who would be alternately tormented with the most insupportable *heat* when nearest the sun; and in the opposite point with the greatest possible *cold*.

Sir Isaac Newton, amongst other purposes which he thinks they may be designed to serve, adds, " that, for the conservation of the water and moisture of the planets, comets seem absolutely requisite, from whose condensed vapours and exhalations, all the moisture which is spent in vegetation, and turned into dry earth, &c. may be supplied and recruited; for all vegetables grow and increase wholly from fluids; and again, as to their greatest part, by putrefaction, into earth. Hence, the quantity of dry earth must continually increase, and the moisture decrease, and be quite evaporated, if it did not receive a continual supply from *some* part or other of the universe;"—" and I suspect," adds this philosopher, " that the *spirit*, which makes the finest, subtilest, and best part of our air, and which is absolutely requisite for the life and being of all things, comes from the comets."

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF GALILEO.

Galileo, the celebrated astronomer and mathematician, was the son of Vincenzo Galilei, a nobleman of Florence, not less distinguished by his quality and fortune, than conspicuous for his skill and knowledge in music; about some points in which science he maintained a dispute with the famous Zarlinas. His wife brought this son, Feb. 19th, 1564, either at Pisa, or, which is more probable, at Florence. Galileo received an education suitable to his birth, his taste, and his abilities. He went through his studies early, and his father then wished that he should apply himself to medicine; but having obtained at College some knowledge of mathematics, his genius declared itself decisively for that study. He needed no directions where to begin. Euclid's Elements were well known to be the best foundation in this science. He therefore set out with studying that work, of which he made himself master without assistance, and proceeded thence to such authors as were in most esteem, ancient and modern. His progress in these sciences was so extraordinary, that in 1589, he was appointed Professor of Mathematics in the University of Pisa, but being there continually harrassed by the scholastic professors, for opposing some maxims of their favourite Aristotle; he quitted that place at the latter end of 1592, for Padua, whither he was invited very handsomely to accept a similar professorship; soon after which, by the esteem arising from his genius and erudition, he was recommended to the friendship of Tycho Brahe. He had already, even long before 1586, written his " Mechanics," or a treatise of the benefits derived from that science and from its instruments, together with a fragment concerning percussion, the first published by Mercennus, at Paris, in 1634, in " Mersenni Opera," vol. 1. and both by Menoless, vol. 1.; as also his " Balance," in which, after Archimedes's problem of the crown, he shewed how to find the proportion of alloy, or mixt metals, and how to make the said instrument. These he had read to his pupils soon after his arrival at Padua, in 1593.*

While he was professor at Padua, in 1609, visiting Venice, then famous for the art of making glass, he heard of the invention of the telescope by James Metius, in Holland. This notice was sufficient for Galileo; his curiosity was raised; and the result of his inquiry was a telescope of his own, produced from this hint, without having seen the Dutch glass. All the discoveries he made in astronomy were the easy and natural consequences of this invention, which opening a way, till then unknown, into the heavens, gave that science an entirely new face. Galileo, in one of his works, ridicules the unwillingness of the Aristotelians to allow of any discoveries not known to their master, by introducing a speaker who attributes the telescope to him, on account of what he says of seeing the stars from the bottom of a deep well. " The well," says he, " is the tube of the telescope, the intervening vapours answer to the glasses." He began by observing the moon, and calculating the height of her mountains. He then discovered four of Jupiter's satellites, which he called the Medicean stars or planets, in honour of Cosmo II. grand duke of Tuscany, who was of that noble family. Cosmo now recalled him from Padua, re-established him at Pisa, with a very handsome stipend, in 1610; and the same year, having lately invited him to Florence, gave him the post and title of his principal philosopher and mathematician.

It was not long before Galileo discovered the phases of Venus, and other celestial phænomena. He had been, how-

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* While he was lecturer at Padua, Gustavus-Adolphus, king of Sweden, was one of his hearers. The lectures then given by him still remain at Milan.

ever, but a few years at Florence, before he was convinced by sad experience, that Aristotle's doctrine, however ill-grounded, was held too sacred to be called in question. Having observed some solar spots in 1612, he printed that discovery the following year at Rome, in which, and in some other publications, he ventured to assert the truth of the Copernican system, and brought several new arguments to confirm it.* This startled the jealously of the Jesuits, who procured a citation for him to appear before the holy office at Rome, in 1615, where he was charged with heresy, for maintaining these two propositions; 1st. That the sun is in the centre of the world, and immoveable by a local motion; and 2d, that the earth is not the centre of the world, nor immoveable, but actually moves by a diurnal motion. The first of these positions was declared to be absurd, false in philosophy, and formally heretical, being contrary to the express word of God; the second was also alleged to be philosophically false, and, in a theological view, at least erroneous in point of faith. He was detained in the inquisition till February, 1616, on the 25th of which month sentence was passed against him; by which he was enjoined to renounce his heretical opinions, and not to defend them either by word or writing, nor even to insinuate them into the mind of any person whatsoever; and he obtained his discharge only by a promise to conform himself to this order. It is hard to say whether his sentence betrayed greater weakness of understanding, or perversity of will. Galileo clearly saw the poison of both in it; and therefore following the known maxim, "that forced oaths and promises are not binding to the conscience," he went on, making further new discoveries in the planetary system, and occasionally publishing them with such inferences and remarks as necessarily followed from them, notwithstanding they tended plainly to establish the truth of the above mentioned propositions.

He continued many years confidently in this course, no juridical notice being taken of it, till he had the presumption to publish at Florence his "*Dialogi della due massime Systeme del Mondo, Tolemaico et Copernicano*;" or, Dialogues of the two greatest Systems of the world, the Ptolemaic and Copernican, in 1632. Here, in examining the grounds upon which the two systems were built, he produces the most specious as well as strongest arguments for each of those opinions; and leaves, it is true, the question undecided, as not to be demonstrated either way, while many phænomena remained insolvable; but all this is done in such a manner, that his inclination to the Copernican system might be easily perceived. Nor had he forborne to enliven his production by several smart strokes of raillery against those who adhered so obstinately, and were such devotees to Aristotle's opinions, as to think it a crime to depart from them in the smallest degree. This excited the indignation of his former enemies, and he was again cited before the inquisition at Rome; the congregation was convened, and, in his presence, pronounced sentence against him and his books. They obliged him to abjure his errors in the most solemn manner, committed him to the prison of their office during pleasure, and enjoined him, as a saving penance, for three years, to repeat once a week the seven penitential psalms; reserving, however, to themsleves, the power of moderating, changing, or taking away altogether, or in part, the above-mentioned punishment and penance. Upon this sentence he was detained a prisoner till 1634, and his "Dalogues of the System of the World," were burnt at Rome. We rarely meet with a more glaring instance of blindness and bigotry than this;* and it was treated with as much contempt by our author as consisted with his safety.

He lived ten years after it, seven of which were employed in making still further discoveries with his telescope; but, by continual application to that instrument, added to the damage he received in his sight from the nocturnal air, his eyes grew gradually weaker, till, in 1639, he became totally blind. He bore this great calamity with patience and resignation, worthy of a philosopher. The loss neither broke his spirit, nor hindered the course of his studies. He supplied the defect by constant meditations, by which he prepared a large collection of materials; and began to dictate his own conceptions, when, by a distemper of three months continuance, wasting away by degrees, he expired at Arcetri, near Florence,† Jan. 1642, in the same year that Newton was born. In stature he was small, but in aspect venerable, and his constitution vigorous; in company he was affable, free, and full of pleasantry. He took great delight in architecture and painting, and

* He demonstrated a very sensible change in the magnitude of the apparent diameters of Mars and Venus; a phenomenon of great consequence to prove the Copernican theory.

* It will appear more extraordinary, when it is considered that the prosecution was begun and carried on by the Jesuits, an order instituted to be a seminary of learning, in the view of producing champions of the papal chair.

† In the last eight years of his life he lived out of Florence, sometimes in the neighbouring towns, and sometimes at Sienna.

designed extremely well. He played exquisitely on the lute; and whenever he spent any time in the country, he took great pleasure in husbandry. His learning was very extensive, and he possessed in a high degree a clearness and acuteness of wit. From the time of Archimedes, nothing had been done in mechanical geometry, till Galileo, who, being possessed of an excellent judgment, and great skill in the most abstruse points of geometry, first extended the boundaries of that science, and began to reduce the resistance of solid bodies to its laws. Besides applying geometry to the doctrine of motion, by which philosophy became established on a sure foundation, he made surprising discoveries in the heavens by means of his telescope. He made the evidence of the Copernican system more sensible, when he showed from the phases of Venus, like to those of the moon, that Venus actually revolves about the sun. He proved the rotation of the sun on his axis from his spots; and thence the diurnal rotation of the earth became more credible. The satellites that attend Jupiter in his revolution about the sun, represented in Jupiter's smaller system, a just image of the great solar system; and rendered it more easy to conceive how the moon might attend the earth, as a satellite, in her annual revolution. By discovering hills and cavities in the moon, and spots in the sun constantly varying, he showed that there was not so great a difference between the celestial bodies and the earth, as had been vainly imagined. He rendered no less service to science by treating, in a clear and geometrical manner, the doctrine of motion, which has justly been called the key of nature. The rational part of mechanics had been so much neglected, that hardly any improvement was made in it for almost 2000 years. But Galileo has given us fully the theory of equable motions, and of such as are uniformly accelerated or retarded, and of these two compounded together. He was the first who demonstrated that the spaces described by heavy bodies, from the beginning of their descent, are as the squares of the times; and that a body, projected in any dirction not perpendicular to the horizon, describes a *parabola*. These were the beginnings of the doctrine of the motion of heavy bodies, which has been since carried to so great a height by Newton. In geometry, he invented the cycloid, though the properties of it were afterwards chiefly demonstrated by his pupil Torricelli. He invented the simple pendulum, and made use of it in his astronomical experiments: he had also thoughts of applying it to clocks, but did not execute that design: the glory of that invention was reserved for his son Vicenzio, who made the experiment at Venice in 1649; and Huygens afterwards carried this invention to perfection. Galileo also discovered the gravity or weight of the air, and endeavoured to compare it with that of water, besides opening up several other enquiries in natural philosophy.

Galileo wrote a number of treatises, many of which were published in his lifetime. Most of them were also collected after his death, and published by Mendessi, in 2 vols. 4to. under the title of "*L'Opere di Galileo Galilei Lynceo*," in 1656. Some of these, with others of his pieces, were translated into English, and published by Thomas Salisbury, in his Mathematical Collections, in two vols. folio. A volume also of his letters to several learned men, and solutions of several problems, were printed at Bologna in 4to.

ARCHITECTURE.

OF THE ORDERS OF ARCHITECTURE.

The moderns have applied the term order to those architectural forms, with which the Greeks composed the façades of their temples.

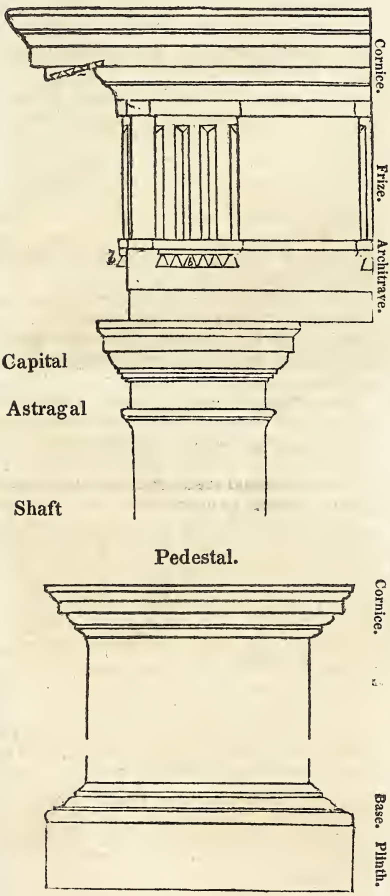
The principle members of an order are, 1st, a platform; 2d, perpendicular supports; and 3d, a lintelling or covering connecting the tops of these supports, and crowning the edifice.

The proportioning of these parts to the edifice and to each other, and at the same time adapting characteristical decorations, constitutes an order, *canon* or rule.

The principal member of an order is the perpendicular support or *column*. The accompaniments being subservient to this leading feature, the bottom of the column is fixed either on a general artificial platform, or each upon a particular *plinth*, or both. The lower part of the column, which rests upon the square plinth, is sometimes encompassed with mouldings, which in allusion to their position, are, in conjunction with the plinth, called the *base*.

The top part of the column is also covered with a square plinth, with its sides straight or curved, and generally accompanied by circular mouldings or sculptured decorations upon the top part of the column, which is immediately underneath it; this, taken together, is called the capital. The body of the column, which reaches between the base and capital, is termed the *shaft:* it is the frustum of a cone, with sometimes a plain surface, but frequently having perpendicular flutings either meeting in an edge, or leaving a small plane space between them. The lintelling or covering, which lies upon and connects the column, is termed the *Entablature*, and is sub-divided into three parts, named architrave, frieze, and cornice: the architrave consists of a mere lintel laid along the tops of the columns; the frieze represents the ends of the cross beams resting upon the former, and having the spaces between filled up, having mouldings also fixed to conceal the horizontal joint, and divide it from the architrave; and the upper member or cornice represents the projecting eves of a Greek roof, showing the ends of the rafters.*

These definitions will be easily understood by an inspection of the following figure.



* Representations of the various mouldings used in architecture will be given in another part of this work

SOLUTIONS OF QUESTIONS.

Quest. 15, *answered by* W. V.

It is evident that the grindstone in question is in form a cylinder, the diameter of which is 36 inches, and altitude 12 inches, wanting two cones, the diameter of each of which is the same as that of the cylinder, viz. 36 in. and the altitude 4 in.

Put $a=,7854$, then according to the rules of mensuration, the solidity of the cylinder will be $36\times36\times a\times12=15552\,(a)$, and the solidity of the two cones will be $36\times36\times a\times4\times\frac{2}{3}$ (Euclid B 12 Prop. 10) $=3456\,(a)$, which taken from the solidity of the cylinder will leave $12096\,(a)$ the solidity of the stone, consequently the solidity of one third of the stone will be $4032\ (a)$ and of two thirds $8064\ (a)$.

Let x denote the third man's share of the semidiameter, then $2\,x$ will be the diameter of his part of the stone, which will also be a cylinder wanting two cones. And these cones will evidently be similar to the two beforementioned, for the solid angle at each of the vertices is common to the two cones on that side the stone, and therefore (Euclid B 11. Def. 24) as 36 the the diameter of each of the larger cones is to 4 the altitude, so is $2x$ the diameter of each of the lesser cones to $\frac{8}{36}\,x$ or $\frac{2}{9}x$ the altitude, therefore the solidity of the two lesser cones will be (Euclid B 12 Prop 10) $4\,ax^2\times\frac{2}{9}x\times\frac{2}{3}=\frac{16}{27}\,ax^3$. But the altitude of the lesser cylinder will be the sum of the altitudes of the lesser cones added to 4 inches, the thickness of the stone at the centre (that is to $\frac{4}{9}x+4$), and therefore its solidity will be $4\,ax^2\times(\frac{4}{9}x+4)=\frac{16}{9}\,ax^3+16\,ax^2$, from which take $\frac{16}{27}ax^3$ the solidity of the two cones, and the remainder $\frac{32}{27}ax^3+16\,ax^2$ will be the solidity of the third man's share of the stone. But one third of the solidity of the stone is also equal to $4032\ (a)$, therefore we have the following equation $\frac{32}{27}ax^3+16\,ax^2=4032\ (a)$ and dividing it by $\frac{32}{27}\,a$ we have $x^3+\frac{27}{2}\,x^2=3402$, from which we obtain $x=11{\cdot}633$, which will be the third man's share of the semidiameter.

Again, suppose y to be the sum of the second and third men's shares of the semidiameter, then the equation will be $y^3+\frac{27}{2}\,y^2=6804$ whence $y=15355$, from which take the third man's share, 11·633, and the remainder 3·722 will be the second man's part of the semidiameter. Again, take 15·355 from 18, and we have 2·645 for the first man's part of the semidiameter of the stone.

This ingenious, but modest correspondent also forwarded a very neat solution of the 14th question; but it was too late for insertion; he also sent a solution of the 17th question.

The proposer of this question sent a very imperfect solution.

QUEST. 17, *answered by* MR. G. FUTVOYE, High-street, Marylebone.

The ends of the block being squares the area of the greater end is $1\frac{1}{4}$ or $(\frac{5}{4})^2 = \frac{25}{16}$; and the area of the lesser end is $(\frac{1}{2})^2 = \frac{1}{4}$ or $\frac{4}{16}$; also $\frac{5}{4} \times \frac{1}{2} = \frac{5}{8}$, or $\frac{10}{16}$. Now $\frac{25}{16} + \frac{4}{16} + \frac{10}{16} = \frac{39}{16} \div 3 = \frac{13}{16}$ mean area, which multiplied by 24 the length of the block, gives $19\frac{1}{2}$ solid feet for the content of the block; and as 1· solid feet of *lignum vitæ* weighs 1327 ozs.*, the whole block ($19\frac{1}{2}$ feet) must weigh $25876\frac{1}{2}$ ounces Avoirdupois.

This question was also answered by the proposer in a somewhat different manner. It was also correctly answered by H. T.; W.V.; Troublesome; and we have received some solutions which are incorrect in principle, and consequently, incorrect in their conclusion.

QUEST. 18, *answered by* Mr. C. A. WILLIAMS *(the proposer).*

It is evident that the figure formed by the shillings will be a polygon of 360 sides, and that the angle at its centre is 1°. Hence by trigonometry its sine 1° is to ·75 in. as sine of 89° 30′, to 42·973, the radius of the required circle; the diameter is therefore 85·946 inches, which squared and multiplied by ·7854, gives 5802· square inches or 40·3 square feet, nearly for the area of the required circle.

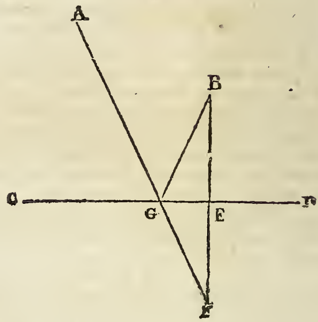
The proposer will perceive that he was not correct in his conclusion, from the alterations we have made in his solution.

We received a solution to this question from Mr. J. M. Edney, one from Mr. Geo. Futvoye, and one from Mr. Hugh Starke; but each of these gentlemen supposes (in this Example), that the perimeter of a polygon and the circumference of a circle circumscribing it, are the same. For they find the circumference of the circle thus, $360 \times \frac{3}{4} = 270$. Now any person may convince himself that this is not correct, by supposing the *polygon* to have only 5 or 6 sides, instead of 360 sides.

The results obtained by the above gentlemen, to *this* question are nearly correct, because the perimeter of a polygon of so many sides does not differ much from its circumscribing circle.—EDIT.

QUEST. 19, *answered* by an ENGINEER, *(the proposer).*

From B one of the given points let fall the perpendicular B E, upon the line C D given in position, and produce it till E F be equal to E B, join A F meeting C D in G; also join B G; A G and B G are the straight lines required.



DEMON. The triangles E B G and E F G having the side B E equal to E F, C E common, and the contained angle B E G equal to F E G equal by Euc. 1 and 4, and consequently the angle B G E is equal F G E or A G C, which was required to be done. The same construction will apply when the points are on opposite sides of the line.

This question was very ingeniously solved by J. B. Oldham, and likewise by Mr. John Holroyd, of the same plaee.

Another gentleman in London, sent a solution, but he will perceive from this construction that he has mistaken the question.

QUESTIONS FOR SOLUTION.

QUEST. 25, *proposed* by Mr. H. FLATHER, Seymour-place.

Required the weight of one of the Portland key stones to the middle arch of Westminster bridge, the diameter of the arch being 76 feet, the height of the key stone 5 feet, the chord of its greatest breadth to the front of the arch 3 ft. 4 in., and its depth in the arch 4 feet?

QUEST. 26, *proposed* by Mr. J. M. EDNEY, St. John's-street, Clerkenwell.

Having given the diameter of a semicircle, it is required to find an algebraic expression for the side of the inscribed square.

QUEST. 27, *proposed* by C. G.

Through a given point, to draw a straight line such that the segments of the line intercepted by perpendiculars let fall upon it from other two given points, shall be equal.

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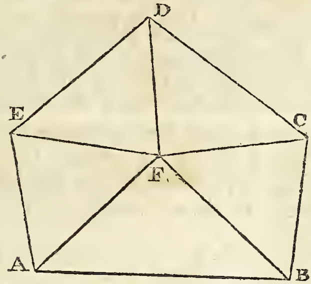
* See the " Artisan" page 25.

GEOMETRY.

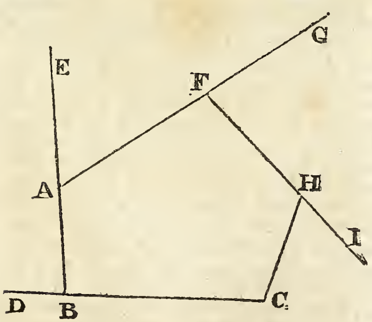
PROPOSITION XXXII.*

Corollary 1st. All the *interior* angles of every rectilineal figure, when four right angles are added to them, make twice as many right angles as the figure has sides. Therefore if *four* right angles be deducted from twice as many right angles as any figure has sides, it will leave the sum of the interior angles of that figure.



For it is evident, that any rectilineal figure, as ABCDE, can be divided into as many triangles as the figure has sides, by drawing straight lines from a point F within the figure to each of its angles. And, by the preceding proposition, all the angles of these triangles are equal to twice as many right angles as there are triangles, that is, as there are sides of the figure; and the same angles are equal to the angles of the figure, together with the angles at the point F, (which do not belong to the figure), that is, together with four right angles. Therefore, the angles of the figure wants four right angles of being equal to twice as many right angles as the figure has sides.

Cor. 2. All the *exterior* angles of any rectilineal figure formed by producing each of its sides, are together equal to four right angles.

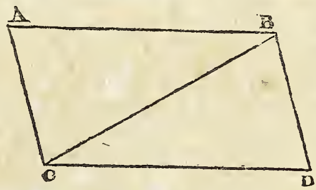


Because every interior angle, as A B C, with its adjacent exterior ABD, is equal to two right angles; therefore all the interior, together with all the exterior angles of the figure, are equal to twice as many right angles as there are sides of the figure; that is, by the foregoing corollary, they are equal to all the interior angles of the figure, together with four right angles; but the interior angles belong to the inside, and are therefore to be deducted, consequently all the exterior angles are equal to four right angles.

PROPOSITION XXXIII.

Theorem.—*The straight lines which join the extremities of two equal and parallel straight lines, towards the same parts, are also themselves equal and parallel.*

Let A B, C D, be equal and parallel straight lines, and joined towards the same parts by the straight lines A C, B D; A C, B D are also equal and parallel.



Join B C; and because A B is parallel to C D, and B C meets them, the alternate angles A B C, B C D are equal; and because A B is equal to C D, and B C common to the two triangles A B C, D C B, the two sides A B, B C are equal to the two D C, C B; and the angle A B C is equal to the angle B C D; therefore the base A C is equal to the base B D, and the triangle A B C to the triangle B C D, and the other angles to the other angles, each to each, to which the equal sides are opposite; therefore the angle A C B is equal to the angle C B D; and because the straight line B C meets the two straight lines A C, B D, and makes the alternate angles A C B, C B D equal to one another, A C is parallel to B D; and it was shewn to be equal to it. Therefore, straight lines, &c. Q. E. D.

PROPOSITION XXXIV.

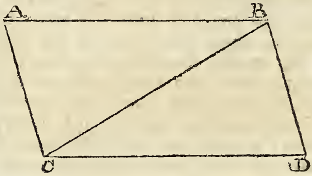
Theorem.—*The opposite sides and angles of a parallelogram are equal to one another, and the diameter bisects it, that is, divides it into two equal parts.**

Let A C D B be a parallelogram, of which B C is a diameter; the opposite

* See page 147.

* A parallelogram is a four-sided figure, of which the opposite sides are parallel; and the diameter is the straight line joining two of its opposite angles.

sides and angles of the figure are equal to one another; and the diameter BC bisects it.



Because A B is parallel to C D, and B C meets them, the alternate angles ABC, B C D, are equal to one another; and because AC is parallel to BD, and BC meets them, the alternate angles A C B, C B D are equal to one another; wherefore the two triangles ABC, CBD have two angles A B C, B C A, in one, equal to two angles B C D, C B D, in the other, each to each, and one side B C common to the two triangles, which is adjacent to their equal angles; therefore their other sides are equal, each to each, and the third angle of the one to the third angle of the other; viz. the side A B to the side C D, and A C to B D, and the angle B A C equal to the angle B D C. And because the angle A B C is equal to the angle B C D, and the angle C B D to the angle A C B, the whole angle A B D is equal to the whole angle ACD: and the angle BAC has been shown to be equal to the angle BDC; therefore the opposite sides and angles of a parallelogram are equal to one another: also, its diameter bisects it; for A B being equal to C D, and B C common, the two A B, B C, are equal to the two D C, C B, each to each; and the angle A B C is equal to the angle B C D; therefore the triangle A B C is equal to the triangle B C D, and the diameter B C divides the parallelogram A C D B into two equal parts. Therefore, &c. Q. E. D.

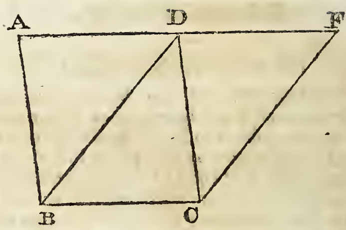
The converse of the former part of this proposition is, "If the opposite sides of a quadrilateral figure be equal, the figure is a parallelogram."

Cor. Hence if the opposite sides of a quadrilateral figure be equal, its opposite angles will likewise be equal; for such a figure is a parallelogram, and the opposite angles are equal, by the Proposition.

PROPOSITION XXXV.

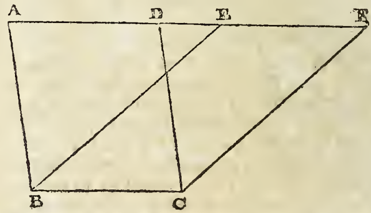
Theorem.—*Parallelograms upon the same base and between the same parallels, are equal to one another.*

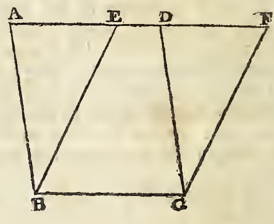
Let the parallelograms A B C D, D B C F be upon the same base B C, and between the same parallels A F, B C; the parallelogram A B C D is equal to the parallelogram D B C F.



If the sides A D, D F of the parallelograms A B C D, D B C F opposite to the base B C be terminated in the same point D; it is plain that each of the parallelograms is double of the triangle B D C; and they are therefore equal to one another.

But, if the sides A D, E F, opposite to the base B C of the parallelograms ABCD, EBCF, be not terminated in the same point:





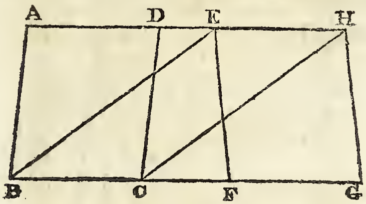
then, because A B C D is a parallelogram, A D is equal to B C; for the same reason E F is equal to B C; wherefore A D is equal to E F; and D E is common; therefore the whole, or the remainder A E is equal to the whole, or the remainder DF; now A B is also equal to D C; therefore the two E A, A B, are equal to the two F D, D C, each to each; but the exterior angle F D C is equal to the interior E A B, wherefore the base E B is equal to the base F C, and the triangle E A B to the triangle F D C. Take the triangle F D C from the trapezium A B C F, and from the same trapezium take the triangle E A B; the remainders will then be equal; that is, the parallelogram A B C D is equal to the parallelogram E B C F. Therefore, parallelograms upon the same base, &c.

Q. E. D.

PROPOSITION XXXVI.

THEOREM. — *Parallelograms upon equal bases, and between the same parallels, are equal to one another.*

Let A B C D, E F G H be parallelograms upon equal bases B C, F G, and between the same parallels A H, B G; the parallelogram A B C D is equal to E F G H.

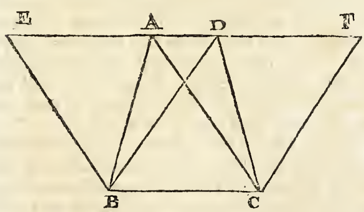


Join B E, C H; and because B C is equal to F G, and F G to E H, B C is equal to E H; and they are parallels, and joined towards the same parts by the straight lines B E, C H: but straight lines which join equal and parallel straight lines towards the same parts, are themselves equal and parallel; therefore E B, C H are both equal and parallel, and E B C H is a parallelogram; and it is equal to A B C D, because it is upon the same base B C, and between the same parallels B C, A H: For the like reasons, the parallelogram E F G H is equal to the same E B C H; therefore also the parallelogram A B C D is equal to E F G H. Wherefore, parallelograms, &c. Q. E. D.

PROPOSITION XXXVII.

THEOREM.—*Triangles upon the same base, and between the same parallels, are equal to one another.*

Let the triangles A B C, D B C be upon the same base B C, and between the same parallels A D, B C: The triangle A B C, is equal to the triangle D B C.



Produce A D both ways to the points E, F, and through B draw B E parallel to C A; and through C draw C F parallel to B D: therefore, each of the figures E B C A, D B C F is a parallelogram; and E B C A is equal to D B C F, because they are upon the same base B C, and between the same parallels B C, E F; and the triangle A B C is the half of the parallelogram E B C A, because the diameter A B bisects it; and the triangle D B C is the half of the parallelogram D B C F, because the diameter D C bisects it: but the halves of equal things are equal; therefore the triangle A B C is equal to the triangle D B C. Wherefore triangles, &c. Q. E. D.

MECHANICS.

OF THE BALANCE.

Although the balance is not considered a distinct mechanical power, being a lever with equal arms, yet it is of so much use in the common affairs of life, and of so great utility in every nice scientific research where quantity is concerned, that we shall endeavour to explain the principles upon which it depends.

The beam of a common balance must have its arms precisely equal in length.

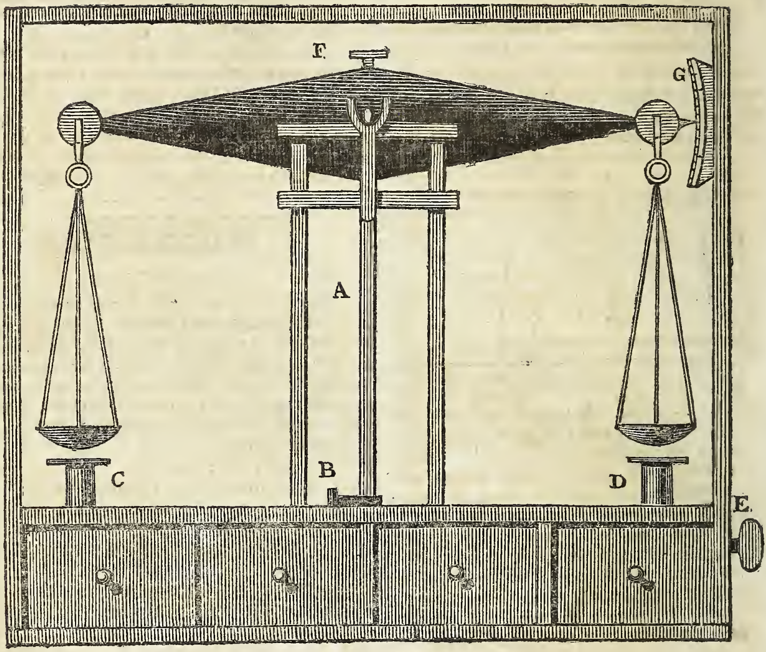
Its axis of motion is formed with an edge like that of a knife, made of hard steel, agate, or garnet; and the two dishes at its extremities are hung upon edges of the same kind. These edges are first made sharp, and then rounded with a fine bone, or a piece of buff leather. The excellence of the instrument depends, in a great measure, on the regular form of this rounded part. When the lever, or beam, is considered as a mere line, the two outer edges are called points of *suspension*, and the inner the *fulcrum*.

The points of suspension are supposed to be at equal distances from the fulcrum, and to be pressed with equal weights when loaded.

The best beams are made of two hollow cones of brass, united at their bases; they are lifted off their supports when the balance is not in use, in order to avoid accidental injuries, the scales are also supported, so as not to hang from the beam, until they have received their weights.

In delicate balances, a small weight is sometimes inclosed within the beam, which is raised or depressed at pleasure, by a screw, so as to bring the centre of gravity of the whole moveable apparatus as near to the fulcrum as may be required, in order to make the vibrations of the beam slow and extensive, and to bring it to the horizontal position, whether the scales have weights in them or not.

The following figure represents a balance made by Fidler for the Royal Institution, London, and nearly resembles those made by Ramsden and Troughton, which will also be noticed in the course of the present article.



The middle column A is raised at pleasure by the cock B, and carries the round ends of the axis in the forks at its upper part, in order to remove the pressure on the sharp edges of the axis within the forks.

The scales are occasionally supported by the pillars C and D, which are elevated or depressed by turning the handle E. The screw F serves for raising or lowering a weight within the conical beam, by means of which the place of the centre of gravity is regulated. The extent of the vibrations is measured on the graduated arc G. This arc is useful for determining the degree of inequality of the weights, by enabling us to ascertain exactly the middle point of the vibrations of the beam.

When a balance is well constructed, it must have the following properties: 1st. it should rest in a horizontal position when loaded with equal weights; 2d. it should have great sensibility; that is, the addition of a small weight in either scale should disturb the equilibrium, and make the beam incline sensibly from the horizontal position; 3d. it should have great stability; that is, when disturbed, it should quickly return to a state of rest.

That the first of these requisites may be obtained, the beam must have equal arms; and the centre of *suspension* must be higher than the centre of *gravity*. Were these centres to *coincide*, the beam, when the weights were equal, would rest in any position, and the addition of the smallest weight would *overset* the balance, and place the beam in a vertical situation, from which it would have no tendency to return. The sensibility in this case would be the greatest possible; but the other two requisites of level and stability would be entirely lost.

When the centre of gravity is lower than the centre of suspension, if the weights be equal, the beam will be horizontal, and if they be unequal, it will take an oblique position, and will raise the centre of gravity of the whole, making the *momentum* on the side of the lighter weight, equal to that on the side of the heavier, so that an equilibrium will again take place.

If the centre of gravity be higher than the centre of suspension, when the beam is level, it will overset by the smallest action, and make a revolution of no less than a semicircle, and the motion will be the swifter the higher the centre of gravity is above the point of suspension, and the smaller the weights with which the beam is loaded.

The second requisite, as already stated, is the *sensibility* of the balance, or the smallness of the weight by which a given angle of inclination is produced.

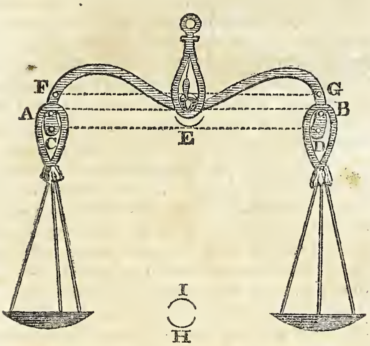
This depends on three circumstances; namely, the length of the arm, the distance between the centres of gravity and suspension, and the weight with which the balance is loaded.

For the sensibility is the greater, the greater the length of the arm, the less the distance between the two centres, and the less the weight with which the balance is loaded.

Lastly, the *stability*, or the force with which the state of equilibrium is recovered, depends chiefly on the two former circumstances; that is, the length of the arm and the distance between the centres of gravity and suspension.

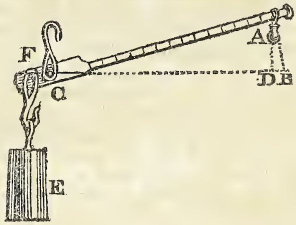
For the diminution of the distance between these centres while it increases the *sensibility*, lessens the *stability* of the balance; but the lengthening of the arm increases the former of these, without diminishing the latter.

These observations, as well as the various kinds of equilibrium, are well illustrated by a balance of the following form.



When the scales are hung on the middle pins, A and B, which are in the same horizontal line with the support of the beam, the equilibrium is neutral, as already observed, or the beam would rest in any position, because the weights would act as if the centre of gravity coincided with the centre of suspension. If the scales be hung on the lowest pins C and D, the centre of gravity will be nearly in the line C D, and its path the curve E, which has its concavity upward. In this case the beam will be level, or the line C D will be horizontal when the scales are loaded with equal weights; but if the scales are hung on the points F and G, the path of the centre of gravity will be convex upwards, and the beam will overset. In reality, the true paths of the centre would be nearly in the curves H and I, situated between the weights in the scales: but these are similar to the other curves.

If the equilibrium be rendered *tottering* by the elevation of the points of suspension of the scales, the lower scale will not rise, even if it be somewhat less loaded than the upper, for in this case the lower weight acts with the greatest advantage: thus, the effect of the weight A is reduced in the proportion of B C to D C,



by the obliquity of the arm C A, while the weight E acts on the whole length of the arm C F.*

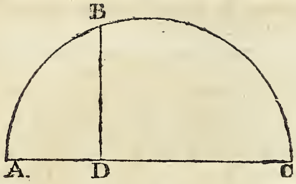
The arms of a balance have sometimes been made unequal for fraudulent purposes, the weight being placed nearer to the fulcrum than the substance to be weighed. This fraud, however, may be detected by changing the contents of one scale into that of the other.

If a counterpoise to the same weight be determined when put in each scale, the sum of both counterpoises will be greater than *twice* the true weight; and the purchaser of any commodity would be sure of having even more than his due, if he could prevail on the seller to weigh *half* in the one scale and *half* in the other.

For example: if one arm of the beam were only three fourths as long as the other, the counterpoise to a weight of twelve ounces, would be *nine* ounces in one scale, and *sixteen* in the other, making together twenty-five instead of twenty-four ounces.

This fact may be illustrated by a very simple figure, as follows: If A B C be a semicircle,

* When the effective length of one or both arms of the beam are capable of being varied, by changing the points of suspension according to the divisions of a scale, the instrument is called a *steelyard*. Where one weight only is used, it is not necessary that the two arms should exactly balance each other, for the divisions may be so placed as to make the necessary adjustment; but it is sometimes convenient to have two or three weights, of different magnitudes, and for this purpose the instrument should be in equilibrium without any weight. There are various forms of the steelyard, each of which has its peculiar advantage. The most useful of these will be described in another part of this work.



and B D represent a given weight, and A D its counterpoise in one of the scales of an unequal balance, then D C will be its counterpoise in the other scale. Now it is evident that A C, or the sum of the two unequal weights is more than twice B D, or double the true weight.

The *true* weight of a substance weighed in a false balance, may be easily determined by a little calculation, as follows:—weigh the substance in each scale, then multiply the two results together, and extract the square root of the product, which will be the *true* weight of the substance under trial.

For example—suppose a substance to weigh 16 ounces in one scale, and 9 ounces in the other; required its true weight? Here 16 multiplied by 9 is 144, the square root of which is 12. The *true* weight of the substance is therefore twelve ounces.

The same thing may also be determined geometrically; thus, draw a straight line A C, (see the foregoing figure), equal to the sum of the two unequal weights, upon which describe a semicircle, divide the line into two parts A D and D C, in the ratio of the weights, then at the point D raise a perpendicular D B, to meet the circumference of the circle, and this line B D will represent the true weight.*

As very delicate balances are not only useful in nice experiments, but are likewise much more expeditious than those that are made for common purposes, they are considered as very valuable instruments, and consequently are not very numerous; we shall therefore conclude this article with a short account of some of the most delicate balances which have yet been constructed.

In the Philosophical Transactions, vol. lxvi. p. 509, mention is made of two accurate balances of Mr. Bolton; and it is said that one would weigh a pound, and turn with $\frac{1}{10}$ of a grain. This, if the pound be avoirdupoise, is $\frac{1}{70000}$ of the weight; and shews that the balance could be well depended on to four places of figures, and probably to five. The other weighed half an ounce, and turned with $\frac{1}{100}$ of a grain. This is $\frac{1}{24000}$ of the weight.

In the same volume, p. 511, a balance of Mr. Read's is mentioned, which readily turned with less than one pennyweight, when loaded with fifty-five pounds, but very distinctly turned with four grains, when tried more patiently. This is about $\frac{1}{96000}$ part of the weight; and therefore this balance may be depended on to five places of figures.

Also, page 576, a balance of Mr. Whitehurst's weighs one pennyweight, and is sensibly affected with $\frac{1}{2000}$ of a grain. This is $\frac{1}{48000}$ part of the weight.

Dr. Ure, of Glasgow, has a pair of scales of the common construction, made in London. With 1200 grains in each scale, it turns with $\frac{1}{70}$ of a grain. This is $\frac{1}{84000}$ of the whole: and therefore about this weight may be known to five places of figures. The proportional delicacy is less in greater weights. The beam will weigh nearly a pound troy; and when the scales are empty, it is affected by $\frac{1}{1000}$ of a grain. On the whole, it may be usefully applied to determine all weights between 100 grains and 4000 grains to four places of figures.

A balance belonging to Mr. Alchorne, of the Mint in London, is mentioned, vol. lxxvii. p. 205, of the Philosophical Transactions. It is true to 3 grains with 15 lb. an end. If these were avoirdupois pounds, the weight is known to $\frac{1}{50000}$ part, or to four places of figures, or rarely five.

A balance, (made by Ramsden, and turning on points instead of edges) in the possession of Dr. George Fordyyce, is mentioned in the seventy-fifth volume of the Philosophical Transactions. With a load of four or five ounces, a difference of one division in the index was made by $\frac{1}{1600}$ of a grain. This is $\frac{1}{384000}$ part of the weight, and consequently this beam will ascertain such weights to five places of figures, beside an estimate figure.

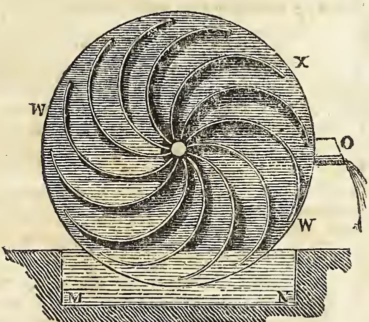
The balance made by the late Mr. Ramsden, for the Royal Society of London, turns on steel edges, upon planes of polished crystal. It is capable of weighing ten pounds, and turns with the one ten millionth of the weight.

* The line A C must be taken from a scale of equal parts, and B D measured upon the same scale. That B D square is equal to the rectangle of A D, and D C, is proved in the 35th prop. 3 B. Euclid.

HYDRAULICS.

SCOOP WHEEL.

The machine called a *scoop wheel* is intended to raise water to a height equal to its semi-diameter. It is represented by the following figure, and consists of a number of semicircular partitions, as may be perceived by an inspection of the following figure:



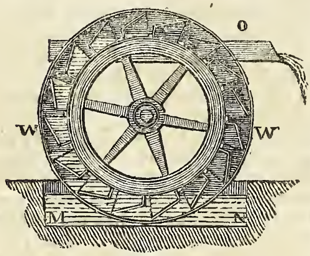
These partitions are open at both ends; that is, at the circumference, and at the centre of the machine. As the wheel is turned round in the direction W X W, either by the hand or by any other power, the scoops take up the water, which gradually descends during the rotation of the wheel, till it runs into its hollow axle, which again discharges it into a spout O. The scoop wheel is one of the forms in which the Persian wheel is often described; but we shall here give a description of that machine as it is usually constructed.

PERSIAN WHEEL.

The Persian wheel is a double water wheel, with float boards on one side, and a series of buckets on the other, which are moveable about an axis above their centre of gravity. The wheel is placed in a stream, which puts it in motion by acting on its float boards. As the wheel turns the moveable buckets dip in the water, and ascend filled with the fluid. But when they reach the highest point, their lower ends strike against a fixed obstacle, so as to make them empty themselves into a reservoir placed at the top of the wheel.

There is another form of the Persian wheel, which is perhaps oftener employed than the one just described, we shall therefore give a representation, and a short description, of it.

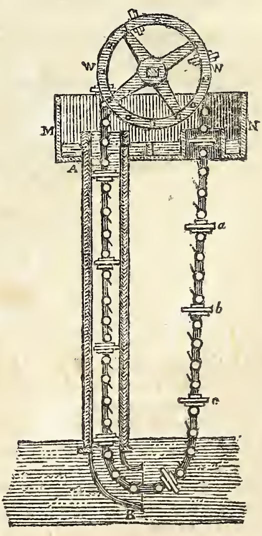
Here W W is a common bucket wheel, moving in the direction W O W. The



buckets dipping in the water M N, rise filled with it, and discharge their contents into the reservoir O, near the summit of the wheel. A wheel of this kind has lately been employed for draining the moss of Blairdrummond in Scotland. It is driven by floatboards fixed on its periphery, or convex circumference, like the common undershot wheel, and a current of water is brought in at a side, to fill buckets placed on the concave side of the rim.

CHAIN PUMP.

The chain pump consists of an endless chain W W B A, which passes round the wheel W W,



enters the water to be raised, and then returns through the tube B A into the cistern M N. This chain carries a number of flat cylindrical pistons *a*, *b*, *c*, of nearly the same diameter as the tube A B, one half of each piston being received into openings in the circumference of the wheel.

When the wheel is put in motion, the pistons enter the barrel B A, and pushing the water before them, raise it into the reservoir M N. When the wheel is turned with great velocity, the barrel is generally filled with water.

Pumps of this kind are frequently placed in an inclined position, and they raise the greatest quantity of water in this position, when the distance of the flat piston is equal to their breadth, and when the inclination of the barrel is about 24°. The Spanish Noria, described at page 153, is the same as a chain pump, the earthen pitchers supplying the place of a chain.

Machines of this kind are sometimes called *cellular pumps*, and when stuffed, cushions are used in place of pistons, they are called *paternoster pumps*.

The Chinese work their cellular pumps, by walking on bars which project from the axis of the wheel, or drum that drives them.

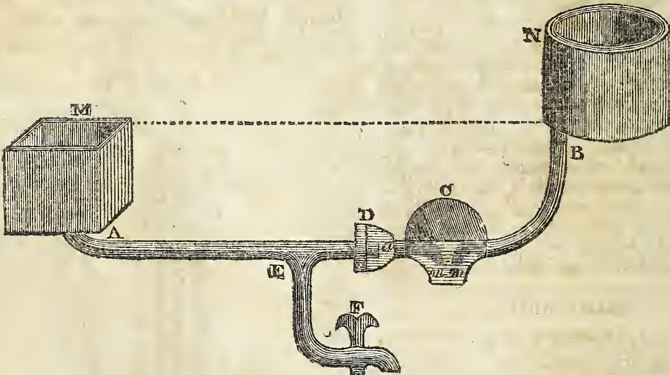
Whatever objection may be made to the choice of machines of this kind, the Chinese mode of communicating motion to them must be allowed to be advantageous.

The chain pump generally used in the navy, is one with flat boards united to the chain, instead of cylindrical pistons, as represented in the foregoing figure. The barrel is usually square, and through it leathers strung on a chain, are drawn in constant succession; but these pumps are only employed when a large quantity of water is to be raised, and then they must be worked with considerable velocity, in order to produce any effect at all.

WHITEHURST'S ENGINE.

Mr. Whitehurst, an ingenious watch-maker of Darby, appears to have been the first person who entertained the idea of raising water by means of its momentum.

A machine upon this principle was erected at Oulton in Cheshire, and is described in the Transactions of the Royal Society of London, for the year 1775; but as it is both a simple and ingenious machine, we shall here give a representation of it.



A M is the reservoir of water, whose surface at M is on a level with B, the bottom of the reservoir B N. The main pipe A E is about 200 yards long, and $1\frac{1}{2}$ inch in diameter, and the branch pipe E F is of such a size, that the cock F is about 16 feet below the surface of the water at M. A valve box with a valve *a* is shewn at D, and C is an air vessel, into which are inserted the extremities *m n* of the main pipe, which are bent downwards for the purpose of preventing the air from being driven out when the water is forced into it. Now, when the cock F is opened, the water will rush out with a velocity of nearly 30 feet per second. A column of water, therefore, 200 yards long and $1\frac{1}{2}$ inch diameter, is now put in motion, and must have a considerable momentum. Hence, if the cock F be suddenly shut, the water will rush through the valve *a* into the air vessel C, and condense the included air. This condensation will take place every time that the cock is opened, so that the included air being compressed, will press upon the water in the air vessel, and raise it into the reservoir B N.

This machine is the same in principle as the *hydraulic ram*, invented by Montgolfier, and differs from it only in this, that a similar effect to opening the cock in Whitehurst's machine, is produced by the motion of the water in Mongolfier's.

The *hydraulic ram* was constructed by Montgolfier in the year 1797, and has been brought to a very perfect state by a series of improvements, which he has successively made upon it. The latest of these, which has been made public, was added in 1816; but as drawings of the machine are absolutely necessary, to render a description of it intelligible, we must reserve our account of it for another part of this work.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF THE LATE MR. RAMSDEN.

Jesse Ramsden was born at Halifax, in Yorkshire, on the 16th of October, 1730. At an early period he conceived a strong desire of devoting himself to literature, and especially to history and antiquities: the mathematics and chemistry engaged his attention also in their turn; but his father was anxious that he should pursue some occupation which might be useful to him; and as he was a clothier, young Ramsden applied to the same employment till he had attained to the age of twenty-one. He then went to London, to seek for some occupation more suited to his genius. Besides other things, he applied to engraving under Burton:* and a fortunate circumstance conducted him to that object for which nature seemed to have destined him, which was to be the reviver and father of the instrumental part of astronomy. Mathematical instruments were often brought to him to be engraven: the more he examined them the more he was sensible of their defects, and a secret instinct made him desirous of constructing better ones. He therefore resolved to make an attempt in this line: he soon acquired the use of the file, and made himself acquainted with the method of turning brass, and even of grinding glasses. In the year 1763 he constructed instruments for Sisson, Dolland, Nairne, Adams, and other methematical instrument makers. He then established a shop on his own account, in the Haymarket, about the year 1768; from which he removed to Piccadilly in 1775. Having formed a design of examining all the astronomical instruments, he resolved to correct those which being founded on good principles were defective only in the construction, and to set aside those which were wrong in both these respects.

Hadley's sextant, which is so much employed in the British navy, appeared to him one of the most useful, but it was then very imperfect; the essential parts were not of sufficient strength; the centre was subject to too much friction; and the index could be moved several minutes without any change being produced in the position of the mirror; the divisions in general were very coarse: and Mr. Ramsden found that the Abbé de la Caille was right, when he estimated at five minutes the error which might take place in the observed distances of the moon and stars, and which might occasion in the longitude an error of fifty nautical leagues. Mr. Ramsden therefore changed the construction in regard to the centre, and made these instruments so correct as to give never more than half a minute of uncertainty.

The invention of a dividing machine having now become necessary, he employed himself in constructing one, which he did with the greatest success. The dividing machines before used were far from being exact. Graham and Bird employed beam compasses. The latter kept his method a secret till it was purchased from him by the Board of Longitude, in order to be published. Mr. Ramsden had already discovered a method of his own, which in exactness surpassed that of Bird. For large works he continued to use the beam compasses; but as it is necessary in the greater number of common instruments to save time, he employed himself for ten years in improving his dividing machine, and at last brought it to a state in which both ease and expedition are united. With this admirable machine a sextant could be divided in the course of twenty minutes. For the invention of this, Mr. Ramsden received a premium of £600 from the Board of Longitude. The Board of Longitude has often given greater premiums for objects of less utility; but the greatest men do not always obtain the greatest rewards. Newton, indeed, got a place in the mint; but he was not indebted for it to his merit alone.

While Mr. Ramsden was employed on

* Mr. Burton was a thermometer and barometer maker, and divider of instruments. Instruments at this period were divided by means of a plate applied to them, and the divisions were in this manner marked off. Mr. Burton was one of the best workmen of his time, and worked for Short, Bird, and other eminent artists. Mr. Ramsden bound himself apprentice to Mr. Burton for four years; and after his time was expired entered into partnership with Mr. Fairbone, who lived afterwards in New-street, Shoe-lane. This partnership, however, did not long continue. Mr. Ramsden opened a shop on his own account in the Strand, and, having married Miss Dolland, became possessed of a part of Mr. Dollond's patent for achromatic telescopes.

his dividing machine, he improved at the same time other instruments. The theodolite before consisted merely of a telescope, turning on a circle divided at every three minutes, by means of a vernier; but in the hands of Mr. Ramsden it became a new and perfect instrument, which serves for measuring heights and distances as well as for taking angles. He constructed the great theodolite, employed by general Roy for measuring the triangles which join those of England and France, and by which there cannot be an error of a second, though it is only eighteen inches radius. It is furnished with two telescopes, each of which turns on a horizontal axis, and by which the angles between objects more or less elevated are reduced to the horizon, and measured. General Roy measured the angle between the pole star and the sides of his triangles, in order to have the convergency of the meridians such as it is in our oblate spheroid. These operations showed, that the difference between the meridians of the observatories of Paris and Greenwich is 9′ 20″.

The barometer employed for measuring the heights of mountains has been much improved by Mr. Ramsden. His method of marking at the bottom the line of the level, and of looking at the top to the contact of the index with the summit of the mercury, renders it possible to distinguish the hundredth part of a line, and to measure heights within a foot. He showed M. de Luc that it is the summit of the column, and not the part which touches the glass, that ought to be observed; and he caused a table to be engraved, which accompanies his barometers, and which, without calculation, gives the heights of places according to the height of the barometer, and even for different degrees of heat. He also simplified the apparatus for carrying and supporting portable barometers.

Various other philosophical instruments have been made by Mr. Ramsden, and always with new improvements: such as an electric machine; a manometer for measuring the density of the air; an instrument for measuring inaccessible distances, and which renders it unnecessary to measure a base; assaying balances which turn with a ten-thousandth part of the weight.

The pyrometer, destined to measure the dilatation of bodies by heat, afforded exercise also for the talents of Mr. Ramsden; and with the happiest success, as may be seen in the Philosophical Transactions for 1785.

Optics are also very much indebted to Mr. Ramsden for its improvement. He found means to correct the aberration of sphericity and refrangibility in compound eye-glasses applied to all astronomical instruments, and in a new and perfect manner. Opticians had imagined, that this could be accomplished by making the image of the object-glass fall between the two eye-glasses; which was attended with this great inconvenience, that the eye-glass could not be touched without deranging the line of collimation, and the value of the parts of the micrometer. To remedy this inconvenience Mr. Ramsden set out from a very simple experiment, namely, that the edges of an image observed through a prism are less coloured according as the image is nearer the prism; and, in consequence of this truth, he sought for the means of placing the two eye-glasses between the image of the object-glass and the eye, without failing to correct the two aberrations, which he did by changing the radii of the curves and placing the glasses in a manner altogether different from that commonly employed.

He invented also a reflecting object-glass micrometer, a description of which may be seen in the Transactions of the Royal Society of London for 1779. In his paper on this subject he points out the defects and inconveniences of that of Bouguer, first invented in 1748, in which the different positions of the eye, in regard to the pencil of light, cause the two images to appear sometimes to touch each other, sometimes to be separated, and sometimes alternately by a sort of oscillation. He found also that the aberration of the rays, which renders the object badly defined, increased the inconvenience of that instrument. He thought it would therefore be necessary to abandon the principle of refraction, and to substitute that of reflection. This instrument, as simple as ingenious, contains no more mirrors or glasses than what are necessary for the telescope; and the separation of the two images depends only on the inclination of the mirrors, and not on the focus.

He however employed himself in improving the refracting micrometer, and conceived the happy idea of placing this micrometer not towards the object-glass, but exactly in the conjugate focus of the first eye-glass. This micrometer is composed of two plano-convex lenses, which can be moved and form two images, as in the object-glass micrometers; but with this difference, that the rays before they fall on the plano-convex lenses pass through a lens convex on both sides, at a certain distance towards the object-glass. By these means the contrary refraction of the two plano-convex lenses, and the convex lens, corrects the error which takes place in object-glass micrometers, where the image depends only on the focus of the two plano-convex lenses. The image being already considerably magnified before it falls on the refracting micrometer, the imperfection of the glasses can occasion only an insensible error in the measurement of angles. It is true, indeed, that by this position the field of the micrometer will be smaller than what it would be were the micrometer near the object-glass. Mr. Ramsden devised means also for making the images to be uniformly illuminated in every part of the field. With this micrometer the diameter of the planets may be measured in every direction; it may be adapted to achromatic telescopes of every kind; it may be brought near to or removed from the object-glass at pleasure, to render vision distinct; and it may be taken from the tube of the eye-glasses, that the telescope may be employed without a micrometer. All these advantages have given great reputation to Ramsden's micrometers, and the astronomer who can now obtain one of them may consider himself fortunate.

In consequence of these and other inventions, Mr. Ramsden was elected a fellow of the Royal Society in 1786.

The objects hitherto mentioned, however, are not the most important of the works of Mr. Ramsden. The equatorial, the transit instrument, and quadrant, received in his hands new improvements. The equatorial first constructed by Sisson, and which was somewhat improved by Short, was much further improved by Ramsden. He first suppressed the endless crew, which by pressing on the centre destroyed its precision. He placed the centre of gravity on the centre of the base, and caused all the movements to take place in every direction. He pointed out the means of rectifying the instrument in all its parts; and he applied to it a very ingenious small machine for measuring or correcting the effect of refraction. This invention is much anterior to that given by Mr. Dolland in the Philosophical Transactions. Mr. Ramsden had a patent for this kind of equatorial. The honourable Stewart Mackenzie, brother of the Earl of Bute, the friend and patron of Mr. Ramsden, wrote a description of this machine, which has been printed. But Mr. Ramsden did not always strictly adhere to the description; for his inventive genius rarely allowed him to construct the same instrument in the same manner.

The transit instrument is employed in all the large observatories of Europe; but Mr. Ramsden has added to it several improvements. He invented a method of illuminating the wires, by making the light pass along the axis of the machine. The reflector is placed in the inside, and obliquely in the middle. He did not lessen the aperture of the object-glass: and as the light passes through a coloured prism, which may be moved at pleasure, the light may be increased or diminished.

Ramsden's meridian telescopes, such as those at Blenheim, at Manheim, at Dublin, and such as those made for the observatories of Paris and Gotha, are also remarkable for the excellence of the object-glasses.

The mural quadrant is the most important of all the astronomical instruments, and Mr. Ramsden has distinguished himself here also by the exactness of his divisions: he placed the thread and plummet behind the instrument, in order that it may not be necessary to remove it when observations are made near the zenith. His method of illuminating the object-glass and at the same time the divisions, and of suspending the telescope, was more perfect than any previously in use. In those of eight feet which he made for the observatories of Padua and Vilna, and which Dr. Maskelyne examined, the greatest error does not exceed two seconds and a half.

The mural quadrant of the Duke of Marlborough at Blenheim, which is six feet, is one of the instruments which was made by Mr. Ramsden. It is fixed to four pillars which turn on two pivots, so that the instrument may be placed north and south in a minute. This instrument is as beautiful as it is perfect.

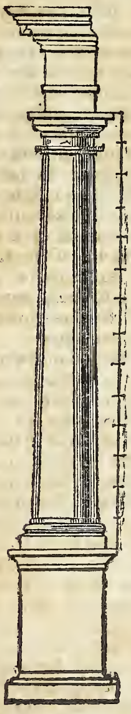
But the quadrant was not the instrument which Mr. Ramsden valued most. It was the whole circle; and he has proved that to attain to the utmost degree of precision of which observation is susceptible, we must renounce the quadrant entirely. His principal reasons are: 1st. The least variation in the centre is perceived by the two points diametrically opposite. 2d. As the circle is turned the plane is always rigorously exact; which cannot possibly be the case in the quadrant. 3d. Two measurements can always be had of the same arc; which serves for verifying the accuracy of the observation. 4th. The first point of the division can be verified every day with the greatest ease. 5th. The dilatation of the metal is uniform, and can produce no error. 6th. This instrument is a meridian telescope as well as a mural. 7th. It becomes a moveable azimuth circle by adding a horizontal circle below the axis, and then gives the refractions independently of the measure of time.

Mr. Ramsden constructed a circle of five feet radius for M. Piazzi, of Palermo, one for the Observatory of Paris, one for Dublin, of twelve feet, besides several others, and continued to exert his ingenuity in the improvement, and construction of philosophical instruments till within a very short time of his death, which took place in the year 1800. He had seven children, but none of them are now alive.

ARCHITECTURE.

We have already stated at page 154, that the orders as now executed are five in number; viz. the Tuscan, Doric, Ionic, Corinthian, and Composite; the first and last of which are Roman, and the others Greek. These orders are chiefly distinguished from each other by the *column* with its *base* and *capital*, and by the *entablature*.*

TUSCAN ORDER.

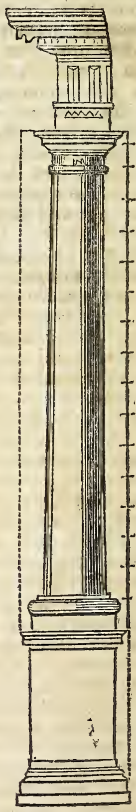


The title of this order leads us to assign its origin to Tuscany, in Italy; and this conjecture is strengthened by the inhabitants of that country being admitted to be the offspring of the *Dorians*.

The Tuscan order is characterized by its plain and robust appearance, and is therefore used only in works, where strength and plainness are required: it has been used with great effect and elegance in that durable monument of ancient grandeur, Trajan's Column, at Rome. But the best modern example of this order is St. Paul's Church, Covent Garden, London.

No ancient remains of this order having been discovered with *entablatures*, it is only from the accounts given by Vitruvius, that the form and ratio of its members can be determined; he allows *seven diameters* for the *height* of the *columns*, and diminishes the upper part one fourth of half the diameter; the *base* is half a diameter in height, one half of which is given to a circular *plinth*, and the other to a *torus**; the *capital* is also half a diameter in height, and one in breadth upon the *abacus*†; the height is divided into three parts, one of which is given to the *abacus*, one to the *eschinus*, and the third to the *hypotrachelian* and *apophygis*; the *architrave* has two faces, with an aperture between them of about an inch and a half for the admission of air to preserve the beams; the lower face is vertical upon the edge of the top of the column; the *frieze* is plain and flat; the *mutules*, or ornamental parts of the *cornice* project over the beams, equal to one fourth of the height of the column.

DORIC ORDER.



* The Entablature is an ornament or assemblage of parts, supported by a column over the capital: each order of columns has a peculiar entablature divided into three principal parts, the architrave, the frieze, and the cornice. See fig. page 175.

* A *torus* or tore is a large semicircular moulding, used in the base of a column.

† The *abacus* is the upper member of a column, which serves as a covering to the capital.

This is the most ancient of the five orders, and while employed by the Greeks, was without a base; the surface of its shaft is usually found worked into twenty very flat flutes, meeting each other at an edge, which is sometimes a little rounded; the upper member of the capital is a square abacus or thin plinth, under which is a large and elegantly formed ovolo, with a great projection; immediately under the ovolo, there are three fillets or annulets, which project from the continued line of the under part of the ovolo, and have equally recessed spaces between them; the flutings of the column are terminated by the under side of the last of these three fillets, and either partly or entirely in a plane at right angles with the axis of the column.

The *architrave* is composed of one vertical face, with a band or fillet at its upper edge; to the underside of this band are suspended a small fillet and conical drops or *guttæ*, which, for their position, are dependent upon the ordnance of the frieze.

The *frieze* consists of rectangular projections and recesses placed alternately. The height of each projection or tablet is rather more than its breadth.

The recesses are either perfectly or nearly square. The tablets are each cut vertically into two angular channels, with two half ones on the extreme edges; each channel is formed by two planes meeting at its bottom at a right angle, and each forming an angle of 135 degrees with the face of the tablet.

The upper ends of the channels are terminated in various forms; the tablets are, from their channellings, named triglyphs; in a direction immediately under each triglyph, and equal to its breadth, a small fillet is attached to the lower side of the architrave crowning band, and from it depend six guttæ or drops, which are generally the *frusta*, or lower parts of cones with their bases downwards, though they are sometimes of a cylindrical shape.

The square spaces in the frieze between the triglyphs, are named metopes, and are frequently decorated with sculptures.

The *cornice* is strongly marked by a corona of great projection, forming a very distinct separation between its upper and lower parts; and by having, below the corona, and immediately over the triglyphs, blocks, named mutules, which also project considerably, and have the plane of their soffits with an inclination from their roofs towards the horizon, and these have likewise guttæ or drops depending from their soffits.

The established proportions for the construction of the doric order are the following. Considering the diameter that of a circle, at the lower end of a shaft, the column is six diameters in height. The thickness of the upper end of the shaft is three-fourths of the lower, or it diminishes one-fourth of the diameter.

The height of the capital is half a diameter. That of the ovolo, with the annulets, and that of the abacus, are each one-quarter of the upper diameter. The annulets are one-fifth of one of the parts. The horizontal dimensions of each face of the abacus is six times its height. The entablature is divided into four equal parts; the upper one is the height of the cornice; the remaining ones are divided equally between the architrave and frieze. The inner edge of the angular triglyph is placed in a vertical line with the axis of the column. The height of the triglyph is divided into five equal parts; three of these parts give the distance of its returning face, and determine also that of the *epistyle*, and consequently include the breadth of the triglyph. The height of the capital of the triglyph is one-seventh of its whole height, and the capital of the metope one-ninth. The breadth of the triglyph is divided into nine equal parts, giving two to each *glyph*, one to each semi-glyph, and one to each of the three inter-glyphs.

The metopes are square. The height of the cornice is divided into five equal parts; the lower is given to the fillet, the mutules, and drops; the next two to the corona; and the remaining two parts are subdivided and disposed among the members.

The projection of the cornice is equal to its height; it is divided into four equal parts, giving three to the projection of the corona.

The number of annulets in the capital vary from three to five; and the number of horizontal grooves, which separate the shaft from the capital, vary from one to three.

In the application of the Doric Order to temples, the shafts of the columns are generally placed upon three steps, which are not proportioned like those in a common stair, but to the magnitude of the edifice.

ON THE STRONGEST FORMS OF COLUMNS, WALLS, &c.

The strongest form of a substance included by horizontal surfaces, or cut out of a horizontal plank, for supporting a weight at its extremity, is that of a triangle. The same form is also the stiffest. For supporting a weight distributed uniformly throughout its length, the form must be that of a parabola, with its convexity turned inwards.

For a vertical plank, bearing a weight at its extremity, the strongest and stiffest form is that of a common parabola, with its convexity outwards. If the weight is equally divided, it must be a triangle.

To support its own weight, it must have for its outline a common parabola, with its convexity inwards. If such a plank were supported by its lateral adhesion only, its outline must be a logarithmic curve, to sustain its own weight.

A horizontal column turned in a lathe, or having all its transverse sections similar, must have its outline a cubical parabola, convex outwards, in order to support the greatest weight at its extremity. The same form is also the stiffest. To support a weight equally distributed through the length, the curve must be a semicubical parabola. To support its own weight, the outline must be a common parabola, convex towards the axis, having its vertex at the extremity.

A triangular prism fixed at one end, with its edge uppermost, is weaker than if its depth were reduced to eight ninths, by cutting away the edge. With a certain force, such a beam would crack at its edge, and not break off.

If a beam, supported at both ends, have all its transverse sections similar, the two portions must have their outlines cubic parabolas. For a weight equally divided, or applied to any point at pleasure, the cube of the diameter must be as the square of the segments.

A wall, turning a vertical face to the wind, ought to have the other face an inclined plane, in order to resist the force of the wind to the greatest advantage, if made of cohesive materials; but if loose materials, it ought to be convex and parabolic behind.

A cohesive wall, supporting a bank of earth or a fluid with its vertical face, ought to be concave behind, in the form of a semicubical parabola, with its vertex at the top of the wall: but if the materials are loose, the back of the wall should be an inclined plane.

A pillar or column of cohesive materials, formed to resist the wind, must be a cone or a pyramid; of loose materials, a parabolic conoid; to support its own weight only, a pillar must have the logarithmic curve for its outline.

A mortise hole should be taken out of the middle of a beam, not from one side; but if it is on the concave side, and is filled up with hard wood, it does not diminish the strength. For similar reasons, a piece spliced on, to strengthen a beam, should be on the convex side. If a cylinder is to be supported at two points with the least strain, the distance between the points should be ·5858 of the length.

If a piece be spliced on a divided beam, equal in depth to half the depth of the beam, the strength is greater than that of the entire beam, in the ratio of 1 to 1·054, very nearly.

Coulomb found the lateral cohesion of brick and stone only $\frac{1}{44}$ more than the direct cohesion, which, for stone, was 215 pounds for a square inch; for good brick from 280 to 300. Supposing this lateral cohesion constant, a pillar will support twice as much as it will suspend, and its angle of rupture will be 45°. From the same supposition it may be inferred, that the strongest form of a body of given thickness for supporting a weight, is that of a circle, since the power of the weight in the direction of every section varies as the length of that section; and the strength is therefore equal throughout the substance. But if the cohesion is increased, like friction, by pressure, and supposing, with Amantons, that this increase, for brick, is three fourths of the weight, the plane of rupture of a prismatic pillar will form, according to Coulomb, an angle of 63° 26′ with the horizon, and the strength will be doubled. On both suppositions the strength is simply as the section.

ON THE INTENSITY OF WIND.

Miles in 1 h.	Force on a square foot in pounds av. by calculation.	Character.
1	0·005	Hardly perceptible.
2	0·020	Just perceptible.
3	0·049	Gentle winds.
4	0·070	Gentle winds.
5	0·123	Gentle winds.
	0·130	A gentle wind.
	0·260	Pleasant wind.
10	0·492	Pleasant brisk gale.
	0·521	Fresh breeze.
15	1·107	Brisk gale.
20	1·968	Very brisk.
	2·604	Brisk gale.
25	3·075	Very brisk.
30	4·429	High wind.
35	5·208	High wind.
	6·027	High wind.
40	7·873	Very high.
45	9·963	Great storm.
	10·416	Very high.
50	12·300	Storm, or tempest.
	15·625	Storm.
60	17·715	Great Storm.
	20·833	Great Storm.
66	21·435	Great Storm.
	26·041	Very great storm.
80	31·490	Hurricane.
	31·250	Hurricane.
	36·548	Great hurricane.
	41·667	Very great hurricane.
	46·875	Most violent hurricane.
100	49·200	Hurrricane that tears up trees and throws down buildings.
	52·083	
	57·293	
109	58·450	Observed by Rochon.

TO PREPARE STARCH FROM POTATOES.

Grind a quantity of potatoes into a pulp by rubbing them on a plate of tin in which a number of holes have been made, then put them into a hair sieve, and pour cold water over them as long as a milky liquid passes through. This liquid is to be received into a basin, and when a whitish powder has settled at the bottom, the liquid is to be poured off it, and the powder repeatedly washed with spring water, until it become perfectly white. When the last liquor has been poured off, the basin is to be placed in a warm place till the starch be perfectly dry.

Observation.—Twenty pounds of good potatoes, treated in this way, generally yields about four pounds of starch.

TO ETCH DESIGNS ON GLASS.

Cover the glass all over with a thin coat of bees' wax, and trace the design with an etching needle; then spread the whole over as uniformly as possible with fluor spar (Derbyshire spar) to the depth of an eighth of an inch, and when this is done, pour sulphuric acid, diluted with three times its weight of water, upon the spar. After the acid has remained upon it three or four hours it is to be poured off, and the glass washed with oil of turpentine; the etching will then appear, and the parts that were covered with the wax will have remained untouched.

Observation.—By this means glass vessels are graduated and ornamented very easily.

SOLUTIONS OF QUESTIONS.

The content of the chain is $3 \times 3 = 9$ solid inches, and the specific gravity of gold is 19·300, which is also the ounces that one cubic foot (1728 inches) of gold weighs*
Hence, 1728 : 19300 :: 9 : 100·521 oz. gold.
1728 : 1000 :: 9 : 5·21 oz. water

Weight of gold in water 95·311
And taking the specific gravity of silver at 10450,
10450 : 1728 :: $14\frac{1}{2}$: 2·4 in. nearly, which, multiplied by 8·85, the difference between the specific gravity of gold and silver, gives 21·24 oz.; and this subtracted from 95·311 oz. (the weight, supposing the whole chain gold) leaves the weight of the chain 74·07 ounces. And 19300 : 1728 :: 74·07 : 6·632 inches pure gold, which, added to 2·4 inches of silver, gives 9·032 cubic inches, the bulk of the chain, or the number of cubic inches of water displaced; hence, $9·032 - 9 = ·032$, and this divided by 9, the area of the bottom of the vessel gives ·00355 in.—the additional height to which the water would rise.

In this question the words "in water," ought to be omitted.

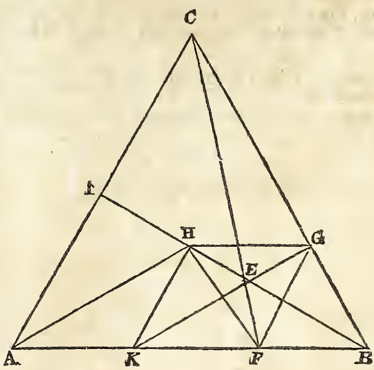
In the solution sent us by the proposer of this question, the weight of an inch of gold is taken only at 9·962 oz., and one of silver at 5·556. Now the former is 11·17, &c. and the latter 6·047. This mistake has led him to a wrong conclusion

We also received a solution to this question from a Correspondent, who signs S., but he has not fully understood the question.

* See "Artisan," page 25 and 26.

Quest. 22, *answered* by J. Millward, *Hammersmith.*

Let A B be the given finite straight line required to be trisected; then on A B



describe an equilateral triangle A B C; bisect the angle at B by the line B D, and bisect B D in E; from C through E draw C E, and produce it till it meet A B in F; take any point G in B C, and through G draw G H parallel to B F, and through F draw F H parallel to B G, meeting each other in H; join F G, and through H draw H K parallel to G F; and the given finite straight line A B is trisected, or divided into the three equal parts B F, F K, K A.

DEMONS. Join G K, and through H draw H A parallel to G K; then because the figures HAKG, HKFG, and HFBG are parallelograms, the opposite sides of which are equal to one another, (Euc. 1 and 34,) therefore the lines B F, F K, K A are respectively equal to the line G H, and therefore B F, F K, K A are equal to one another. Euc. Axiom 1.

This question might have been solved more simply; for by bisecting the angles B A C, and A B C, and drawing H K, parallel to A C, and H F parallel to B C, and the thing was done, and might easily be demonstrated to be so.

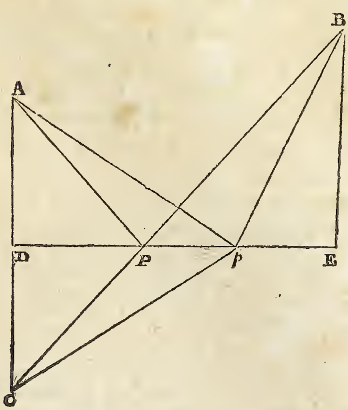
This question was also solved by J. B. *of Oldham.*

QUEST. 23, *answered* by G. G. C. *(the proposer.)*

If a pendulum vibrate in a circle, and if g be the velocity acquired by a body descending freely, in one second of time, p the ratio of the circumference of a circle to its diameter, and l the length of the pendulum vibrating in one second, in any latitude, then it may be demonstrated that $g = p^2 l$. Hence, in the present example,* $(3{\cdot}1416)^2 \times \left(\frac{39{\cdot}2}{12}\right)$ the length of the pendulum in feet at the Pole, gives 32·24 feet, for the velocity acquired by a heavy body falling freely in one second at the Pole.

By the same theorem g, or the force of gravity at latitude 45°, in the present example, is 32·158; and at the equator 32·076.

QUEST. 24, *answered* by G. G. C.



Let A and B be the given points, and D E the line given in position; from A and B let fall the perpendiculars A D and B E, and produce A D to C, making C D equal to D A. Join B C cutting D E in P, and also join A P; then A P and P B, shall be less than any other two lines A P and P B drawn from A and B to any other point P in the line D E.

DEMON. Because A D is equal to D C, and D P common to the two triangles A D P and C D P, and the angles at D right angles, the sides A P and C P are equal.

In the same manner it may be shown, that A P and P C are equal. Hence A P and B P are together equal to B C, and A P and B P are equal to C P and P B. Now (Eucl. 1 and 20) B C is less than B P and P C, and therefore A P and P B are less than A P and P B.

This question was solved nearly in the same manner, by Mr. JOHN HOLROYD, Teacher, *Oldham.*

QUESTIONS FOR SOLUTION.

QUEST. 28, *proposed* by ALFRED EQUALITY.

In the city of Pisa in Tuscany, is a circular building called the Hanging-tower, which is said to have been 188 feet in height, its inclination from the perpendicular is such, that the top projects 16 feet over the base, or horizontal plane, 6 feet of the tower having sunk on one side below its original site. Required the diameter of the tower?

QUEST. 29, *proposed* by Mr. G. FUTVOYE, *High-street, Mary-le-bone.*

What will be the diameter of a globe, when the solidity and superficial content are expressed by the same number?

QUEST. 30, *proposed* by J. B. *of Oldham.*

What is the solid content of a cube, the greatest line that can be drawn in it being 9 inches?

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* The number 3·1416 is the circumference of a circle, whose diameter is 1.

THE GREAT LORD BACON,

London; Published by Hodgson & Co. 10, Newgate St.

MEMOIR OF THE LIFE OF FRANCIS BACON,

LORD VERULAM, VISCOUNT ST. ALBAN'S.

Francis Bacon, Lord High Chancellor of England under King James I. was son of Sir Nicholas Bacon, lord keeper of the great seal, in the reign of Queen Elizabeth, by Anne, one of the daughters of Sir Anthony Cooke, and eminent for her skill in the Greek, Latin, and Italian languages. He was born at York House, in the Strand, on the 22d January, 1560. He gave early proofs of a surprising strength and pregnancy of genius, and when a mere boy, was distinguished by persons of worth and dignity for something far beyond his years. Queen Elizabeth, a very acute discerner of merit, was so charmed with the solidity of his sense and the gravity of his behaviour, that she would often call him "her young Lord keeper," an office which he eventually reached, although not in her reign. When qualified for academical studies, he was sent to the University of Cambridge, where, June 10, 1573, he was entered of Trinity College, under Dr. John Whitgift, afterwards Archbishop of Canterbury. Such was his progress under this able tutor, and such the vigour of his intellect, that before he had completed his sixteenth year, he had not only run through the whole circle of the liberal arts, as they were then taught, but began to perceive the imperfections of the reigning philosophy, and meditated that change of system which has since immortalized his name, and has placed knowledge upon its most firm foundation. Extraordinary as this may appear, he was heard, even at that early age, to object to the Aristotleian system, the only one then in repute, and to say, that his "exceptions against that great philosopher, were not founded upon the worthlessness of the author, to whom he would ever ascribe all high attributes, but for the unfruitfulness of the way: being a philosophy only for disputations and contentions, but barren in the production of works for the benefit of the life of man."

He went to France with Sir Amias Powlet, then the queen's ambassador at Paris, who intrusted him with a commission to the queen, which he discharged with great approbation, and returned again to France. During his absence, his father died in 1579; upon which he returned to England, and applied himself to the study of the common-law, which he resolved upon as his profession, though his inclinations led him much more strongly to affairs of state. He was appointed one of the queen's council when he was but twenty-eight. And to her he dedicated his Elements and Maxims of the Common-law, in 1596, though they were not printed till after his death. In 1597 he published a work of another kind, entitled, "Essays, or Counsels Civil and Moral." This work is well known, and has been often reprinted. The author appears to have had a high opinion of its utility; and of the excellent morality and wisdom it inculcates, there probably never has been but one opinion. Some of these essays had been handed about in manuscript, which he assigns as a reason why he collected and published them in a correct form.

In the last ten years of the queen's reign he made a great figure in the House of Commons, and there he applied himself to politics: so much so, that the Queen and Lord Treasurer Burleigh employed his head and hand in matters of state. He was in his younger years attached to the interests of the Earl of Essex, whom he endeavoured to dissuade from those rash measures which proved his ruin. About 1605 he married Alice, daughter of Benedict Barnham, Esq. alderman of London, a lady who brought him an ample fortune, but by whom he never had any children.

Upon the accession of King James he was soon raised to considerable honours. In the first year of his reign he was knighted at Whitehall, and next year was made one of the King's counsel learned in the law. He wrote in favour of the union of the two kingdoms of Scotland and England, which the King so passionately desired. In 1607 he was appointed solicitor-general. In 1611 he was made joint-judge with Sir Thomas Vavasor, then knight-marshal of the knight-marshal's court; and in 1613 he succeeded Sir Henry Hobart as Attorney-general; in 1616 he was sworn one of the Privy Council. He then applied himself to reducing and recomposing the Laws of England. He distinguished himself when attorney-general by his endeavours to restrain the custom of duelling then very frequent. In 1617 he was appointed Lord-keeper of the Great Seal, and in 1618 he was made Lord Chancellor of England, and created Lord Verulam.

In the midst of these honours and a multiplicity of business, he did not forget his beloved philosophy. In October, 1620, he published his great work, entitled. "*Novum Organum*," the design of which was, to advance a more perfect method of using the rational faculty than men were before acquainted with, in order to raise and improve the understanding, as far as its present imperfect state admits, and enable it to conquer and interpret the difficulties and obscurities of nature. This work his majesty, (to whom he sent a copy,) received as graciously as he could wish, and wrote him a letter respecting it, which certainly does honour to both their memories. He received also the compliments of many learned men on the same subject, and had every reason to be satisfied with the general reception of a work, which cost him so much time and pains. Such is said to have been his anxiety for its perfection, that he revised and altered *twelve copies* before he brought it to the state in which it was published.

January 27, 1621, he was advanced to the dignity of Viscount St. Alban's, and appeared with the greatest splendour at the opening of the session of parliament on the 30th of that month. But he was soon after surprised with a reverse of fortune. For about the 12th of March following, a committee of the House of Commons was appointed to inspect the abuses of the Courts of Justice. The first thing they fell upon was bribery and corruption, of which the Lord Chancellor was accused by Aubrey and Egerton, who affirmed, that they had procured money to be given to him, to promote their causes depending before him. On Monday, April 29, he sent his confession and submission to the House of Lords, in which he confessed some facts, denied some, and palliated others. The lords agreed to sequester the seal; and on May 3d, the Lord Chief Justice pronounced the following sentence: "That the Lord Chancellor should pay a fine of £40,000, and be imprisoned in the Tower, during the King's pleasure; that he should be for ever incapable of any office, place, or employment in the state, and never to sit in Parliament, or come within the verge of the Court." There is a variety of opinions concerning his guilt of the points charged against him. He retired after a short imprisonment, from the engagement of an active life, which he had been called to much against his genius, to the shade of a contemplative one, which he had always loved. The king remitted his fine, and granted it to some of his lordship's friends, in order to give him a little respite from creditors, to whom he is said to have paid £8000 after his fall. "And the poor remains (as he tells us in one of his letters) which he had of his former fortunes in plate and jewels, he had paid to poor men to whom he owed, scarcely leaving himself a convenient subsistence." In 1624, in a most pathetic letter, he implored the king to grant a total remission of his sentence, in order that the blot of ignominy which he laboured under might be removed. The request was granted him: for we find he was summoned to Parliament in the first year of King Charles I. It appears from the works he composed during his retirement, that his thoughts were still free, vigorous, and noble. In his retirement he composed the greatest part of his English and Latin works. He was taken ill at the Earl of Arundel's house at Highgate, and there expired on the 9th of April, 1626, in the 66th year of his age. He was buried in St. Michael's church, at St. Alban's, according to the direction of his last will, and had a monument of white marble erected to him by Sir Thomas Meautys, who had formerly been his secretary, and afterwards Clerk of the Privy Council, under two kings.

If we contemplate the personal character and mental powers of Lord Bacon, he will appear to be one of the *greatest* and wisest men that ever contributed to human knowledge. "The only thing," says Brucker, "to be regretted in the writings of Bacon is, that he has increased the difficulties necessarily attending his original and profound researches, by too freely making use of new terms, and by loading his arrangement with an excessive multiplicity and minuteness of divisions. But an attentive and accurate reader, already not unacquainted with philosophical subjects, will meet with no insuperable difficulties in studying his works; and, if he be not a wonderful proficient in science, will reap much benefit as well as pleasure from the perusal. In fine," adds this judicious writer, "Lord Bacon, by universal consent of the learned world, is to be ranked in the first class of modern philosophers." He unquestionably belonged to that superior order of men, who, by enlarging the boundaries of human knowledge, have been benefactors to mankind; and he may not improperly be styled, on account of the new track of science which he employed, the *Columbus* of the philosophical world.; and it may be justly said, that his learning and knowledge was a century in advance of the times in which he lived.

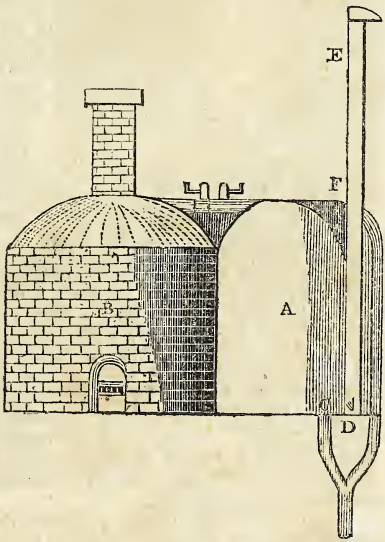
In his will he has this remarkable passage,—"For my name and memory I leave it to men's charitable speeches, and to foreign nations, and the next ages."

His works, collected into five vols. 4to. were beautifully and accurately printed by Bowyer and Strahan, in 1765, and have been lately reprinted in 8vo.

PNEUMATICS.

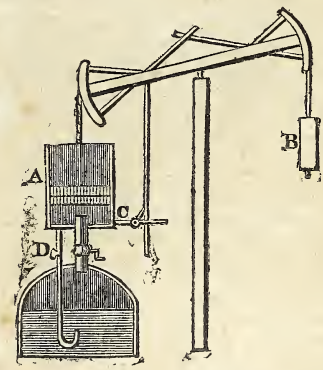
STEAM ENGINE.

The steam engine is perhaps the most magnificent effort of mechanical power; it has undergone successive changes, and it appears to have been brought very near to perfection by the improvements of the late Mr. Watt. The pressure of steam was first applied by the Marquis of Worcester, and afterwards by Savery, to act immediately on the surface of water contained in a close vessel, and this water was forced, by the elasticity of the steam, to ascend through a pipe, as in the following figure, which represents the original steam engine as constructed by Mr. Savery.



The vessel A being filled with steam from the boiler B, and the stopcock being turned, the steam cools and is condensed, and the water is forced into its place by the pressure of the atmosphere, through the valve C: the steam is then readmitted, and forces the water to ascend through the valve D and the pipe D E. The vessel F acts alternately with A.

A great degree of heat, however, was required for raising water to any considerable height by this machine: for, in order that steam may be made capable of supporting, in addition to the atmospherical pressure, a column of 34 feet of water, its temperature must be raised to 248° of Fahrenheit, and for a column of 68 feet, to 271°; such a pressure, also, acting on the internal surface of the vessels, made it necessary that they should be extremely strong; and the height to which water could be drawn up from below, when the steam was condensed, was limited to 33 or 34 feet. However a still greater objection was, the great quantity of steam necessarily wasted, on account of its coming into contact with the cold water and the receiver, the surfaces of which required to be heated to its own temperature, before the water could be expelled; hence a tenth or a twentieth part only of the steam produced could be effective; and there would probably have been a still greater loss, but for the difficulty with which heat is conducted downwards in fluids. These inconveniences were, in a great measure, avoided in Newcomen's engine, where the steam was gradually introduced into a cylinder, and suddenly condensed by a jet of water, so that the piston was forced down with great violence by the pressure of the atmosphere, which produced the effective stroke: this effect was, however, partly employed in raising a counterpoise, which descended upon the readmission of the steam, and worked a forcing pump in its return, when water was to be raised. This engine is represented by the following figure.



Here the steam being admitted into the cylinder A below the piston, the weight B is allowed to descend: a jet of water is then admitted by the pipe C, which condenses the steam, and the pressure of the atmosphere then depresses the piston: a part of this water is admitted by the pipe D into the boiler, in order to keep it sufficiently full.

Though this manner of condensing the steam was rapid, yet it was neither instantaneous nor complete, for the water injected into the cylinder had its temperature considerably raised by the heat emitted by the steam during its condensation; it could only reduce the remaining steam to its own temperature, and at this temperature it might still retain a certain degree of elasticity; thus, at the temperature of 180°, steam is found to be capable of sustaining about half the pressure of the atmosphere, so that the depression of the piston must have been considerably retarded by the remaining elasticity of the steam, when the water was much heated. The water of the jet was left off when the piston was lowest, and was afterwards pumped up to serve the boiler, as it had the advantage of being already hot. In this, as well as in other steam engines, the boiler is furnished with a safety valve, which is raised when the force of the steam becomes a little greater than that of the atmospheric pressure; and it is supplied with water by means of another valve, which is opened, when the surface of the water within it falls too low, by the depression of a block of stone, which is partly supported by the water.

The alternations of heat and cold to which the cylinder was exposed by the jet of cold water, and by exposure to the air, in the old engines, reduced their power nearly to half its real value, so that the moving force, instead of amounting to 14 lb. on every square inch of the area of the piston, was reduced to little more than 7 lb.

The late justly celebrated Mr. Watt avoided this inconvenience, by performing the condensation in a separate vessel, into which a small jet is flowing without intermission; and by introducing the steam alternately above and below the piston, the external air is wholly excluded; the piston rod working in a collar of leather, so that the machine has a double action, somewhat resembling that of Lahire's double pump; and the stroke being equally effectual in each direction, the same cylinder, by means of an increased quantity of steam, performs twice as much work as in the common engine. We might also employ, if we thought proper, a lower temperature than that at which water usually boils, and work in this manner with a smaller quantity of steam; but there would be some difficulty in completely preventing the insinuation of the common air. On the other hand, we may raise the fire so as to furnish steam at 220° or more, and thus obtain a power somewhat greater than that of the atmospheric pressure; and this is found to be the most advantageous mode of working the engine; but the excess of the force above the atmospheric pressure, cannot be greater than that which is equivalent to the column of water descending to supply the boiler, since the water could not be regularly admitted, in opposition to such a pressure. The steam might also be allowed to expand itself within the cylinder for some time after its admission, and in this manner it appears from calculation, that much more force might be obtained from it than if it were condensed in the usual manner, as soon as its admission ceases; but the force of steam thus expanding, is much diminished by the cold, which always accompanies such an expansion, and this method would be liable to several other practical inconveniences.

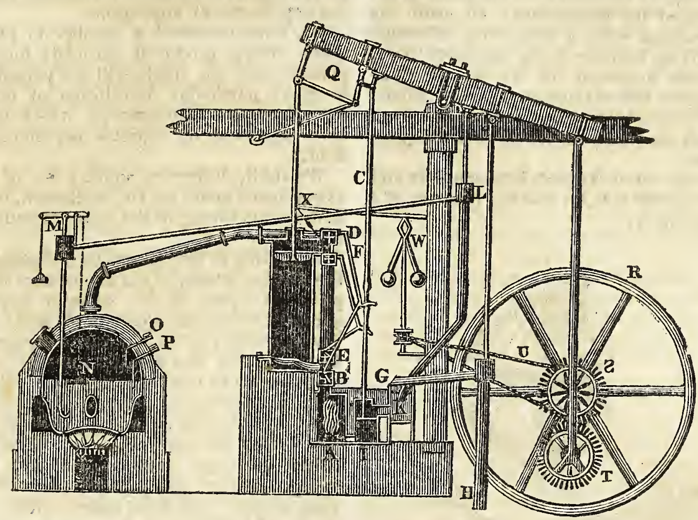
The peculiarities of Mr. Watt's construction require also some other additional arrrangements; thus, it is necessary to have a pump, to raise not only the water out of the condenser, but also the air, which is always extricated from the water during the process of hoiling. If the water employed has been obtained from deep wells or mines, it contains more air than usual, and ought to be exposed for some time in an open reservoir before it is used; for it appears that the quantity of air, which can be contained in water, is nearly in proportion to the pressure to which it is subjected. The admission of the steam into the cylinder is regulated by the action of a double revolving pendulum. The piston is preserved in a situation very nearly vertical, by means of a moveable parallelogram, fixed on the beam, which corrects its curvilinear motion by a contrary curvature. In the old engines, a chain working on an arch was sufficient, because there was no thrust upwards. When a rotatory motion is required, it may be obtained either by means of a crank, or of a sun and planet wheel, with the assistance of a fly wheel; this machinery is generally applied to the opposite end of the beam; but it is sometimes immediately connected with the piston, and the beam is not employed. The cylinder is usually inclosed within a case, and the interval is filled with steam, which serves to confine the heat very effectually.

When the water which produces the condensation of the steam is to be raised from a great depth, a considerable force is sometimes lost in pumping it up. Hence, Mr. Watt proposed to employ steam at a very high temperature, and to let it escape when its elasticity is so reduced by expansion, as only to equal that of the atmosphere. The air pump is also unnecessary in this construction. But there must always be a very considerable loss of steam, and though the expense of fuel may not be increased quite in the same proportion as the elasticity of the steam, yet the difference is probably inconsiderable.

But previous to considering this subject, and that of the modern high pressure engines, we shall here give a representation and description of Mr. Watt's single acting engine.

The following is a representation of this engine.

MR. WATT'S STEAM ENGINE.



The steam, which is below the piston, is suffered to escape into the condenser A by the cock B, which is opened by the rod C, and at the same time, the steam is admitted by the cock D into the upper part of the cylinder; when the piston has descended, the cocks E and F act in a similar manner in letting out the steam from above and admitting it below the piston. The jet is supplied by the water of the cistern G, which is pumped up at H from a reservoir: it is drawn out, together with the air; that is, extricated from it by the air pump I, which throws it into the cistern K, from whence the pump L raises it to the cistern M; and it enters the boiler through a valve, which opens whenever the float N descends below its proper place. The pipes O and P serve also to ascertain the quantity of water in the boiler. The piston rod is confined to a motion nearly rectilinear by the frame Q*; the fly wheel R is turned by the sun and planet wheel S and T; and the strap U turns the centrifugal regulator W, which governs the supply of steam by the valve or stopcock X.

* The nature of this motion will be fully explained, in treating of the different parts of the steam engine.

OPTICS.

UNUSUAL REFRACTION OF THE ATMOSPHERE.

Although the phenomena of unusual *refraction* have been often observed by astronomers and navigators, yet they do not seem to have attracted particular notice till the year 1797. The unusual elevation of coasts, mountains, and ships, have been long known under the name of *looming;* and the same phenomena, when accompanied with inverted images, have been distinguished in France by the name of *mirage.*

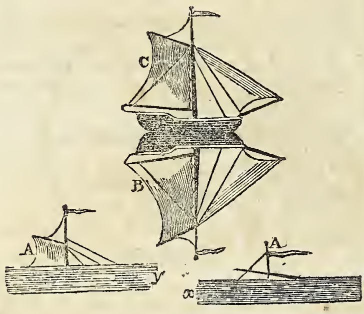
Mr. Huddart seems to have been the first person who described an inverted image beneath the real objects; he accounts for this, and other phenomena of elevation, by supposing that, in consequence of the evaporation of the water, the refractive power of the air is not greatest at the surface of the sea, but at some distance above it, increasing gradually from the surface of the sea to a line, which he calls the *line of maximum density,* and thence diminishing gradually till it becomes insensible.

He then shows, that, in passing through such a medium, the *rays of light* would move in curve lines convex upwards, when they passed above the line of maximum density, and convex downwards when they passed below that line.

Hence, two pencils from the object will arrive at the eye, which will produce an *inverted image* of the object.

In the year 1798, the Rev. Dr. Vince, of Cambridge, made a series of interesting observations at Ramsgate, on the unusual refraction of the atmosphere. He made his observations with a terrestrial telescope magnifying between thirty and forty times, when the height of the eye was about 25 feet above the surface of the sea. Sometimes the height of the eye was 80 feet; but this produced no variation in the phenomena.

On the 1st of August, between four and eight o'clock P. M. he saw the topmast of a ship as at A,



above the horizon $x\ y$ of the sea: at the same time, he also discovered in the field of view *two* complete images, B, C, of the ship in the air, vertical to the ship itself, B being *inverted*, and C *erect*, having their hulls joined. As the ship receded from the shore, less and less of it's mast became visible; and as it *descended*, the images B and C *ascended;* but as the ship did not recede below the horizon, Dr. Vince did not observe at what time, and in what order, the images vanished.

He then directed his telescope to another ship A,

whose hull was just in the horizon $x\ y$, and he observed a complete inverted image B, the mainmast of which just touched that of the ship itself. In this case there was no second image as before. While the ship A moved along, B followed its motion, without any change of appearance.

Dr. Vince observed a number of other ships, which produced variously formed images; but our limits will not permit us to give a particular description of them, nor of similar appearances which have been observed on various occasions at *land*.*

We shall, however, notice a few of the experiments made by Dr. Wollaston, to illustrate his theory of the cause of unusual refraction.

According to this ingenious philosopher, the *varying density* of the atmosphere is the principal cause of the singular appearances which we have just mentioned; and from a number of interesting experiments, he found, that the results were perfectly conformable to this hypothesis.

He took a square phial, and poured a small quantity of clear *syrup* into it, and above this an equal quantity of *water*, which gradually incorporated with the syrup, between the pure water and the pure syrup. The word *syrup* written on a card, and held behind the bottle, appeared erect through the pure syrup; but when seen through the visible medium of the syrup and water, it appeared inverted with an erect image above.

Dr. Wollaston then put nearly the same quantity of *rectified spirit of wine* above the water, and he observed a similar appearance; only in this case, the true place of the object was seen uppermost, and the inverted and erect images below.

When the variations of density are great, the object may be held close to the phial; but when they become more gradual, the object is only elongated, and in order to be seen inverted, must be held one or two inches behind the phial.

By examining an oblique line seen in this way, he found, that the appearances continue many hours even with *spirit of wine;* with *syrup*, two or three days; with *sulphuric* acid, four or five; and still longer with a solution of *gum-arabic*.

Dr. Wollaston next heated a poker red hot, and looked along the side of it at a paper ten or twelve feet distant. A perceptible refraction took place at a distance of three-eighths of an inch from it. A letter, more than three-eighths of an inch distant, appeared erect as usual; at a less distance there was a faint reversed image of it; and still nearer the poker was a second image erect.

Although the experimental method of illustrating the phenomena of unusual refraction, as given by Dr. Wollaston, is in

* This subject has been fully treated by Dr. Wollaston, in the Philosophical Transactions for 1810.

every respect an excellent one, yet the employment of different fluids does not represent the case which actually exists in nature.

The method employed by Dr. Brewster seems more agreeable to nature.

His method consists in holding a *heated iron* above a mass of water, bounded by parallel plates of glass.

As the heat descends through the fluid, a regular variation of density is produced, which gradually increases from the surface to the bottom.

If the heated iron be withdrawn, and a cold body substituted in its place, or even the air allowed to act alone, the superficial strata of water will give out their heat so as to have an increase of density from the surface to a certain depth below it. Through the medium thus constituted, all the phenomena of *unusual refraction* may be seen in the most beautiful manner; the variation of density being produced by heat alone.

ON THE COLOURS OF THE ATMOSPHERE.

If the earth's atmosphere consisted of a medium unlimited, and perfectly homogeneous, the sun and planets would shine in a firmament of the most intense darkness, similar to what has been observed by travellers on the elevated summits of the Alps and the Andes.

As the atmosphere, however, is of a limited extent, and composed of strata of variable density, the light of the sun which falls upon it is reflected in every direction, and reaches the surface of the earth with that chaste tinge of blue, which forms such a fine relief to the yellowish light of the heavenly bodies.

The blue colour of the sky was attributed by Fromondus, Otto Guericke, Wolfius, and Muschenbroek, to a mixture of light and shadow. Sir Isaac Newton and Bouguer, on the contrary, were of opinion, that the particles of air reflect the *blue* rays more copiously, and transmit the *red*.

This explanation, which was then little better than a mere conjecture, has been rendered highly probable by the experiments of Dr. Brewster on the polorisation of light.

The phenomena of blue shadows, which have been so often observed, arise from the illumination of the shadows of bodies by the blue light of the sky, the parts without the shadow being illuminated by some other light, such as that of the sun or of a candle. These coloured shadows are generally seen with most distinctness at sun-rise and sun-set, when the sun's light has a yellow tinge.

The colours of shadows illuminated by the sky, vary in different countries, and with different seasons of the year, from pale blue to a violet black; and when there are yellow vapours in the horizon or yellow light reflected from the lower part of the sky, either at sun-rise or sun-set, the shadows have a strong tinge of green, arising from the mixture of these accidental rays with the blue tint of the shadow.

The phenomena of coloured shadows are often finely seen in the interior of a room. They arise from the blue light of the sky, and the light reflected either from the furniture, or the painted walls of the room.

M. Hassenfratz has written a very elaborate memoir on the subject of coloured shadows, and has deduced the following conclusions from his various experiments and observations.

1. That the shadows formed by the direct light of the sun and that of the atmosphere, vary from *meadow green* to a *violet black*, in a gradation through the *blue*, *indigo*, and *violet*; and that the variation depends on the intensity of the light of the sun, compared with that of the atmosphere.

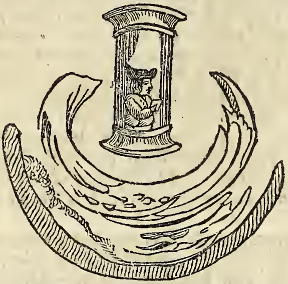
2. That the shadows formed in apartments by the light of the atmosphere and reflected lights, may present all the prismatic colours, more or less changed by black.

3. That the shadows produced on a piece of pasteboard, illuminated by artificial light, are reddish and blueish, more or less deep; and, that very probably, the blueish and reddish tints of the shadows, depend on the proportion of hydrogen and carbon in the combustible bodies.

ON CYLINDRICAL MIRRORS.

If the surface of a metalic cylinder be highly polished, and the cylinder set upon its base, near a picture lying horizontally, the image of the picture seen by reflection from the polished surface, is distorted in the most irregular manner, in consequence of the surface of the mirror being plane in a section passing through its axis, circular in a section perpendicular to this, and of a different curvature in all intermediate sections. On the contrary, we may conceive a picture distorted according to given laws, which, when seen by reflection in the cylindrical mirror, shall appear of the most just and harmonious proportions. This, accordingly, is the purpose for which cylindrical mirrors are used. They are generally accompanied with a set of distorted figures, which have neither shape nor meaning when seen by themselves; but when they are placed in a particular position before a cylindrical mirror, their image is at once reduced into form and expression.

The effect of a cylindrical mirror is shown by the following figure.



CHEMISTRY.

AZOTE, OR NITROGEN.*

Azote, or nitrogen, is a simple body in the same condition with respect to us as oxygen, with which it has a very strong tendency to combine. It cannot be procured perfectly pure. It is always either combined with caloric in the form of a gas, or exists in a liquid or solid state in certain natural and artificial compounds, from which chemists procure it in the state of gas. If it exists alone, either in the sol id or liquid form, in nature, it has hitherto eluded the researches of chemists.

Like oxygen, azote remained for a long time unknown. It was discovered in 1772 by the late Dr. Rutherford, Professor of Botany, in the University of Edinburgh.

It has since been procured by Scheel, Berthollet, and Lavoisier, by very different processes.

That by which Scheel procured it was the following: He mixed about equal weights of iron filings and sulphur into a paste with water, and placed the mixture in a proper vessel, over water supported on a stand; he then put an inverted glass jar full of *atmospherical* air over it, and allowed this to stand exposed to the mixture two or three days.

He perceived by the ascent of the water, that the air in the jar gradually diminished in bulk, but at the end of the third day the water ceased to rise in the jar: he therefore examined the air which remained in the jar, and found it to be azotic gas.

Lavoisier's method of procuring it is much quicker. He decomposed atmospherical air by burning phosphorus in a vessel containing a given quantity of it.

The readiest way of procuring it is, therefore, to put a small piece of phosphorus into a tea-cup raised on a stand above the surface of the water, contained in the pneumatic trough, then to set fire to the phosphorus, and quickly invert a jar over it filled with atmospherical air. As soon as the combustion ceases, the jar will appear to be about three-fourths full of air of a very white colour, which, upon standing a short time over the water, will become perfectly transparent. This air is azotic or nitrogen gas, tolerably pure.

There are other methods of procuring it, but the following process, first pointed out by Berthollet, furnishes it nearly *pure*, if the proper precautions be attended to. Very much diluted *nitre acid (aqua-fortis)* is poured upon a piece of muscular flesh, in a retort and a heat of about 100 degrees applied to it. A considerable quantity of azotic gas is then produced, which may be received into proper vessels placed on the shelf of the pneumatic trough.

1. The air of the atmosphere contains about 0·78 parts (in bulk) of azotic gas; almost all the rest of it is oxygen gas. Mr. Lavoisier was the first philosopher who published this analysis, and who made azotic gas known as a component part of air. His experiments were published in 1773.

2. Azotic gas is invisible and elastic like common air, which it resembles in its mechanical properties. It has no smell. Its specific gravity, according to Kirwan, is 0·985, that of air being 1·000. Lavoisier makes it only 0·978, and with this the statement of Sir H. Davy coincides exactly. According to Mr. Kirwan, 100 cubic inches of it, at the temperature of 60°, barometer 30 inches, weigh 30·535 grains; according to Lavoisier and Davy, they weigh 30·338 grains.

3. It cannot be breathed by animals without suffocation. If obliged to respire it, they drop down dead almost instantly.* No combustible will burn in it. Hence the reason why a candle is extinguished in atmospherical air as soon as the oxygen near it is consumed. Mr. Goettling, indeed, published, in 1794, that phosphorus shone, and was converted into phosphoric acid, in pure azotic gas. Were this the case, it would not be true that no combustible will burn in this gas; for the conversion of phosphorus into an acid, and even its shining, is an actual though slow combustion. Mr. Goettling's experiments were soon after repeated by Drs. Scherer and Jaeger, who found, that phosphorus does not shine in azotic gas when it is perfectly pure; and that therefore the gas on which Mr. Goettling's experiments were made had contained a mixture of oxygen gas, owing principally to its having been

* Nitrogen was the name given to this gas by the French chemists, at the framing of the new nomenclature; but in this country it usually receives the name of azote, or axotic gas.

* Hence the name *azote*, given it by the French chemists, which signifies "destructive to life."

confined only by water. These results were afterwards confirmed by Professor Lampadius and Professor Hildebrandt. It is therefore proved beyond a doubt, that phosphorus does not burn in azotic gas; and that whenever it appears to do so, there is always some oxygen gas present.

4. This gas is not sensibly absorbed by water; nor indeed are we acquainted with any liquid which has the property of condensing it. Mr. Henry ascertained, that when water is previously deprived of all the air which it contains, 100 inches of it are capable of absorbing only 1·47 inches of azotic gas at the temperature of 60°.

When electric sparks are made to pass through common air confined in a small glass tube, or through a mixture of oxygen gas and azotic gas, the bulk of the air diminishes. This curious experiment was first made by Dr. Priestley, who ascertained at the same time, that if a little of the blue infusion of *litmus* be let up into the tube, it acquires a red colour; hence it follows that an acid is generated. Mr. Cavendish ascertained, that the diminution depends upon the proportion of oxygen and azote present; that when the two gases are mixed in the proper proportions, they disappear altogether, being converted into *nitric acid*. Hence he inferred that nitric acid is formed by the combination of these two bodies. This important discovery was communicated to the Royal Society on the 2d June 1785. The combination of the gases, and the formation of the acid, was much facilitated, he found, by introducing into the tube a solution of *potash* in water. This body united with the nitric acid as it was produced, and formed with it the salt called *nitre*. In Mr. Cavendish's first experiments there was some uncertainty, both in the proportion of oxygen gas and of common air, which produced the greatest diminution in a given time, and in the proportion of the two gases which disappeared by the action of the electricity. The experiment was twice repeated in the winter 1787-8 by Mr. Gilpin, under the inspection of Mr. Cavendish, and in the presence of several members of the Royal Society.

2. Nitric acid, which will be more fully described in another part of this work, is a heavy liquid, usually of a yellow colour, which acts with great energy upon most substances, chiefly in consequence of the facility with which it yields a portion of its oxygen. If a little phosphorus or sulphur, for instance, be put into it, the acid when a little heated gives up oxygen to them, and converts them into acids precisely as if the two bodies were subjected to combustion. In this case, the nitric acid, by losing a portion of its oxygen, is changed into a species of gas called *nitrous gas*, which flies off and occasions the effervescence which attends the action of nitric acid on these simple combustibles. Nitrous gas is procured in greater abundance, as well as purity, by dissolving copper or silver in nitric acid. The gas may be received in a water trough in the usual way. It possesses the curious property of combining with oxygen the instant it comes in contact with it, and of forming nitric acid. Hence the yellow fumes which appear when nitrous gas is mixed with common air. This combination furnishes a sufficient proof, that the constituents of nitrous gas are azote and oxygen, and that it contains less oxygen than nitric acid. It is therefore considered as an *oxide of azote*.

3. When iron filings are kept for some days in nitrous gas, they deprive it of a portion of its oxygen, and convert it into a gas which no longer becomes yellow when mixed with common air, but in which phosphorus burns with great splendour, and is converted into phosphoric acid. This combustion and acidification is a proof that the new gas contains oxygen. Its formation demonstrates that it contains azote, and that it has less oxygen than nitrous gas. It is therefore an *oxide of azote* as well as nitrous gas. The name *gaseous oxide of azote* has been given to it.

Thus we find, that azote is capable of uniting with three doses of oxygen, and of forming two oxides and one acid. We shall find afterwards that there is still another acid composed of the same ingredients.

The combinations of azote with simple combustibles are scarcely so numerous; but some of them are of great importance.

1. When putrid urine, wool, shavings of horn, and many other animal substances, are subjected to distillation, among other products, there is obtained a substance which has a very pungent odour, and which is well known under the names of *hartshorn* and *volatile alkali*.* It may be procured in greatest purity from the salt called *sal ammoniac*. Pound this salt, and put it into a flask, together with thrice its weight of ground quicklime, and luting on a bent tube, plunge the extremity of it into a mercurial trough, and apply heat to the flask. A gas comes over, which is *hartshorn* in a state of purity; by chemists it is usually called *ammoniac*. It is light, absorbed in great abundance by water, has a pungent taste, and gives a green colour to vegetable blues. When electric sparks are passed through this gas, its bulk is doubled, and it is converted into a mixture of hydrogen and azotic gases. This

* The term *alkali* is applied in chemistry to a variety of substances, which have the property of giving a green colour to vegetable blues.

is a demonstration of its composition.* But it is difficult to form ammonia by uniting its two elements artficially. However, Dr. Austin succeeded in combining them. When both are in the gaseous state, the union does not take place; but when hydrogen, at the instant of its evolution, comes in contact with azotic gas, ammonia is formed. Dr. Austin filled a jar with azotic gas, placed it over mercury, and let up into it some moistened iron filings. Now iron filings have the property of decomposing water. They unite with its oxygen, and allow its hydrogen to escape. There was suspended in the jar a paper tinged blue with radish. In a day or two it became green, and thus indicated the formation of ammonia; for no gas but ammonia has the property of changing vegetable blues to green. When nitrous gas was substituted for azote, the ammonia was evolved more speedily. The experiment succeeded also with common air, but more slowly.

2. No compound of azote and carbon is at present known; but according to Fourcroy, azotic gas has the property of dissolving a little charcoal. For he says, azotic gas, obtained from animal substances by Berthollet's process, when confined long in jars, deposits on the sides of them a black matter, which has the properties of charcoal.

3. Phosphorus plunged into azotic gas is dissolved in a small proportion. Its bulk is increased about $\frac{1}{40}$, and *phosphuretted azotic gas* is the result, which, if mixed with oxygen gas, becomes luminous, in consequence of the combustion of the dissolved phosphorus.

4. Fourcroy informs us, that when sulphur is melted in azotic gas, part of it is dissolved, and *sulphuretted azotic gas* formed.

As azote has never yet been decompounded, it must, in the present state of our knowledge, be considered as a simple substance. Dr. Priestly, who obtained azotic gas at a very early period of his experiments, considered it as a compound of oxygen gas and phlogiston, and for that reason gave it the name of *phlogisticated air*. Stahl considered combustion as merely the separation of phlogiston from the burning body. But as these theories are now abandoned, and as all the attempts to decompose azote have hitherto failed, we must of necessity consider it as a simple substance. It must be acknowledged, however, that there are several chemical phenomena altogether inexplicable at present; but which might be accounted for if it were possible to prove that azote is a compound, and that one of the component parts of water enters into its composition. One of these phenomena is the formation of RAIN: another is, the constant disengagement of azotic gas when ice is melted. Dr. Priestly found, that when water, previously freed from air as completely as possible, is frozen, it emits, when melted again, a quantity of azotic gas. He froze the same water nine times without exposing it to the contact of air, and every time obtained nearly the same proportion of azotic gas.

* This gas was first analysed by Scheele, but the proportions were accurately ascertained by Berthollet and Austin.

ASTRONOMY.

OF THE MOON.

Next to the sun, the moon is the most remarkable of all the heavenly bodies, and is particularly distinguished by the periodical changes to which figure and light are subject.

The moon is not a *primary* planet, but a secondary, or *satellite*, which revolves round the earth, and accompanies it in its annual revolution round the sun. The mean time of a revolution of the moon round the earth, or the time between two successive conjunctions, is 29 days 12 hours 44 minutes; but the time she takes to perform a revolution round her orbit, is only 27 days 7 hours 43 minutes. The former of these periods is called the *synodical*, and the latter the *periodical* revolution. The difference between these periods is occasioned by the motion of the earth in the ecliptic; for while the moon is going round the earth, the earth advances about 29° in the ecliptic, which is nearly 1° per day, and, therefore, the moon must advance 29° more than a complete revolution round her orbit, before she can overtake the earth, or be again in conjunction with the sun, which will require 2 d. 5 h., her daily motion being about 13 degrees.

Of all the celestial bodies, the moon is the nearest to the earth, her mean distance being only 240,000 miles, which is scarcely a four-hundredth part of the sun's distance from the earth; but her apparent size is nearly equal to that of the sun, she must therefore be a very small body compared with the sun. Her diameter is only about 2161 miles, and therefore the earth is about 48⅘ times greater; but the density of the moon is said to be to that of the earth as 5 to 4 consequently the quantity of matter contained in the earth, is only about 39 times that contained in the moon.

Although the moon moves over a very

considerable portion of her orbit in the course of a day; yet, on account of its smallness, her hourly motion is only about 2290 miles, which is about $\frac{1}{30}$th part of the space passed over by the earth in the same time. But in all her motions the moon is subject to great irregularities, which arise from the eccentricity of her orbit, and her proximity to the earth. The eccentricity of her orbit, as determined from the latest and most accurate observations, is 12,960 miles, or nearly $\frac{1}{18}$th part of her mean distance, of course she is about $\frac{1}{9}$th part nearer the earth on some occasions than at others.

PHASES OF THE MOON.

By Thy command the moon as daylight fades,
Lights her broad circle in the deep'ning shades;
Array'd in glory, and enthroned in light,
She breaks the solemn terrors of the night;
Sweetly inconstant in her varying flame,
She changes still, another, yet the same.
BROOME.

Although the *phases* of the moon are among the most frequently observed phenomena of the heavens, yet they are also among the most wonderful. But on account of the frequency and regularity of the changes in the appearances and situation of this beautiful object, the cause of these phenomena are perhaps less thought of by ordinary observers, than if they were less frequent. The moon being an opaque spherical body, which appears luminous only in consequence of reflecting the light of the sun, can only have that side illuminated which is at any time turned towards the sun, the other side remaining in darkness; and as that part of her can only be seen which is turned towards the earth, it is evident that we must perceive different portions of her illuminated, according to her various positions with respect to the earth and sun.

At the time of conjunction, or when the moon is between the earth and sun, she is then invisible on the earth, because her enlightened side is then turned towards the sun, and her dark side towards the earth. In a short time after the conjunction, she appears like a fine crescent to the eastward of the sun a little after he sets. This crescent begins to fill up, and the illuminated part to increase as she advances in her orbit; and when she has performed a fourth part of a revolution, she appears to be half illuminated, and is then said to be in her first quarter. After describing the second quadrant of her orbit, she is then opposite to the sun, and shines with a round illuminated disc, which is called full moon. Her appearance at this time is very accurately represented by the following figure.

After the full she begins to decrease gradually as she moves through the other half of her orbit; and when the eastern half of her only is enlightened, she is said to be in her third quarter; thence she continues to decrease until she again disappears at the conjunction, as before.* These various phases plainly demonstrate that the moon does not shine by any light of her own; for if she did, being globular, she would always present a fully illuminated disc like the sun. That the moon is an opaque body, is not only proved from her phases, but also by the occultation of stars, for her body often comes between the earth and a star, and while she is passing it, the star is hid from our view.

MOTIONS OF THE MOON.

The neighbouring moon her monthly round
Still ending, still renewing, through mid heaven,
With borrowed light her countenance triform;†
Hence fills and empties to enlighten th' earth,
And in her pale dominion checks the night.

MILTON.

It has already been remarked that the motions of the moon are very irregular. The only equable motion she has, is her revolution on her axis, which is completed in the space of a month, or the time in which she moves round the earth. This has been determined by the important and curious circumstance, that she always presents the *same face* to the earth, at least with very little variation. But as her motion in her orbit is alternately accellerated and retarded, while that on her axis is uniform, small segments on the east and west sides alternately appear and disappear. This occasions an apparent vibration of the moon backwards and forward, which is called her *libration* in longitude.

A little more of her disc is also seen towards one pole, and sometimes towards the other, which occasions another wavering or vacillating kind of motion, called the *libration* in latitude. This shows that the axis of the moon is not exactly, though nearly, perpendicular to the plane of her orbit; for if the axis of the moon were exactly perpendicular to the plane of her orbit, or if her equator coincided with that plane, we should perceive no other libration than that in longitude.

When the place of the moon is observed every night, it is found that the orbit in which she performs her revolution round the earth, is inclined to the ecliptic at an angle of $5^\circ\ 9'$ at a mean rate; this angle is not only subject to some variation, but the very orbit itself is changeable, and does not always preserve the same form: for though it be elliptical, or nearly so, with the earth in one of the foci, yet its eccentricity is subject to some variation, being greater when the line of the *apsides* coincides with that of the *syzygies*, and least when these lines are at right angles to each other. But the eccentricity is always very considerable, and, therefore, the motion of the moon is very unequal, for like all other planets, it is quickest in *perigree* and slowest in *apogee*. At a mean rate she advances, in her orbit, $13^\circ\ 10'$ per day, and comes to the meridian about 48 minutes later every day. As the moon's axis is nearly perpendicular to the plane of the ecliptic, she can scarcely have any change of seasons. But what is still more remarkable, one half of the moon has no darkness at all, while the other half has two weeks of light and darkness alternately. For the earth reflects the light of the sun to the moon, in the same manner as the moon does to the earth; therefore, at the time of conjunction, or new moon, one half of the moon will be enlightened by the sun, and the other half by the earth; and at the time of opposition, or full moon, one half of the moon will be enlightened by the sun, but the other half will be in darkness. The earth also exhibits similar phases to the moon to what she does to the earth, but in a reverse order, for when the moon is *full*, the earth is *invisible* to the moon; and when the moon is *new*, the earth will appear to be *full* to the moon, and so on. It has been already mentioned, that the moon always presents the same face to the earth, from hence it is inferred, that one half of the moon can never see the earth at all; whilst from the middle of the other half it is always seen overhead, turning round almost thirty times as fast as the moon does.

From the circle which limits our view of the moon, only one half of the earth's side next her is seen, the other half being hid below the horizon of all places on that circle.

To the moon, the earth seems to be the largest body in the universe, for it appears about thirteen times greater than the moon does to the earth.

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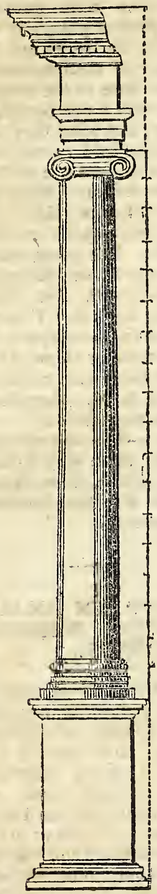
* These various phases may be satisfactorily and pleasantly illustrated, by placing a lighted candle on a table to represent the sun, a smaller at some distance from it to represent the earth, and then carrying a smaller white ball round it to represent the moon revolving round the earth.

† Increasing with horns towards the east; decreasing with horns towards the west; and at the *full*.

Miscellaneous Subjects.

ARCHITECTURE.

IONIC ORDER.



The origin of the Ionic Order is problematical. Vitruvius reports it to have been made in representation of the curls in the head-dress of females; but other hints are quite as probable; such as the spiral shape of the horns of rams; or that assumed by the barks of some trees, when dried in the sun; or the beautiful spiral forms of some sea shells*.

In the *architrave* and *frieze* of this order, all appearances of triglyphs and guttæ are omitted; and in the *cornice*, instead of the bold mutules of the Doric order, the ends of smaller pieces of wood, to which the covering tiles were fixed, are represented by what are termed dentiles or teeth. This order differs also from the Doric, by having a *base* at the lower extremity of the shaft; the propriety of this might have arisen from the diameter of the shaft being much less than that of the Doric, in proportion to the height of the order, or the weight it had to sustain.

The rest of the Ionic order is not so precisely defined, nor so uniformly adhered to, as similar parts of the Doric.

In all the Greek Ionics, the height of the cornice, measured from the lower edge of the corona upwards, appears to have a constant ratio to the total height of the entablature; viz. nearly as 2 to 9, which seems the true one to accord with the character of the order. The great recess of mouldings, under the corona, gives it a striking prominence, and prevents the cornice from appearing too heavy, though both the dentile band and *cymatium* of the frieze are introduced under it. On account of the frieze being wanting in most of the Asiatic remains, although the architrave and cornice have been accurately measured, the height of the entablature cannot be ascertained. The only instance in which a frieze has been discovered is in the theatre of Laodicea; and there it is rather less than one-fifth of the entablature. In the temple of Bacchus at Zeos, and Minerva Polias at Priene, the architraves are divided into three facæ below the cymatium. Their proportions are very different from those at Athens, though also elegant in character and effect.

The *height* of the Ionic columns was originally *eight* diameters, taken at the bottom; but the moderns have increased it to *nine*.

The shaft is generally cut into 24 flutes, with as many fillets. The altitude of the entablature may, in general, be two diameters; but it may be increased, and should not be less than one-fourth of the height of the column in works of magnificence.

It is said, that the temple of Diana at Ephesus, the most celebrated edifice of all antiquity, was of this order. At present, it is much used in churches, courts of justice, and buildings connected with the arts of peace.

ON THE VERNIER SCALE.

The method of dividing, what is termed a vernier scale, is founded on the difference of two approximating scales, one of which is moveable, and the other fixed.

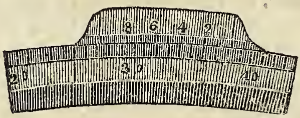
Thus, if a given space on the limb of an instrument be divided into any number of equal parts, and an equal space on an at-

* This part of the order is called the *volute*, and forms the principal characteristic and ornament of the Ionic Order. It is also used in the Composite Order.

tached moveable scale be divided into *one more* part, it is evident, that each of them will be smaller than the former, by that part of one division into which this attached sliding scale is divided.

Therefore, on shifting the attached scale forward, the quantity of aberration, or difference, will diminish at each successive division, till a new coincidence again takes place, and then the number of divisions on the sliding scale will mark the fractional value of the displacement, which will be equal to one of the divisions on the *vernier* or sliding scale.

Thus in the annexed figure, *nine* di-



visions of the primary, or fixed scale, occupy a space equal to ten on the sliding scale, and the moveable *zero* stands beyond the thirty-eighth and thirty-ninth division; therefore, to find how much more than one whole division is indicated by the vernier, it is only necessary to observe, where the opposite sections or lines on the scales coincide, which, in this instance, is opposite to the fourth division of the vernier, or sliding scale. The whole quantity is therefore 38·1.

It is evident, that any *fractional* part of a whole division on the primary or fixed scale, must bear the same proportion to an equal space on the vernier as a *whole* division, or the space occupied by the whole divisions of the vernier.

Hence, one division of the vernier is always equal in value to the quotient of the smallest division on the primary scale, divided by the number of divisions on the vernier.

Thus, suppose one degree on the limb of a Hadley's quadrant to be divided into three equal parts, and that the attached vernier is divided into twenty equal parts: then one division on the vernier indicates one minute; for the third part of a degree is twenty minutes, which divided by *twenty*, the number of divisions on the vernier, quotes *one* minute.

Hence, we have the following simple rule for ascertaining the value of one division of any vernier, attached to a primary scale.

Find the value of the smallest division on the primary scale, and divide this value by the number of divisions on the vernier, and the quotient will be the value of one division on the vernier of the same denomination, as that to which the smallest on the primary scale was reduced, previous to dividing by the divisions on the vernier.

TO STAIN GLASS OF VARIOUS COLOURS.

Procure a large piece of crown window-glass, and place the design (which should be previously drawn on paper) beneath the plate of glass, then brush the upper side of the glass with gum-water, and when this is perfectly dry, it will form a surface proper for receiving the colours without danger of their spreading or running. The outlines of the design are then to be drawn with a fine pencil, in a black or blue colour, and after they are dry the colours are to be laid on with larger pencils. After the colours are all laid on, they are to be again taken off those parts which are intended to be very light: this may be done by a goose quill, cut like a pen, without a slit. The glass must now be burned, in order to fix the colours, or to stain the glass with the colours which have been laid upon it. This operation is best performed in an assayer's furnace, the fire of which must be allowed to die away gradually, as soon as the colours are found to be perfectly fixed, otherwise the glass would become too brittle.

Observation.—The colours and effect of the picture are often very different, when taken out of the fire, from what they were when put into it: this, however, cannot be guarded against.

TO PREPARE AN AMALGAM OF GOLD AND MERCURY FOR WASH-GILDING.

Put a small quantity of gold, with about six times its weight of mercury, into an iron ladle, or crucible, which has been previously rubbed in the inside with whitening, then put it upon a charcoal fire, and submit it to a gentle heat, occasionally stirring the metals with an iron wire. The heat should not be so strong as to evaporate the mercury, at least not till the solution of the gold is nearly effected; the heat may then be increased for a moment, till a vapour is seen to rise from the crucible. When the amalgam is formed, it is to be thrown into water, where a small quantity of mercury will be seen to separate from it. To free it completely from mercury, it will be necessary to twist it up in a piece of fine wash leather, and to press it gently betwixt the finger and thumb. The mercury will then pass through the pores of the leather, and leave the amalgam fit for use, of a fine white colour.

Observation.—It is necessary that both the gold and the mercury should be perfectly pure.

TO GILD AN ALLOY, OR COMPOUND OF BRASS AND COPPER.

Clean the surface of the article to be washed or gilded, by immersing it in diluted nitric acid, and then in water, to prevent the farther action of the acid before the gilding is performed. The article is then to be put into an acid called the *quickening*, which is made by dissolving a little mercury in nitric acid, so as to give it a milky whiteness. The article is to be dipped in this, which will give it a coat of the solution in an instant. After this, the amalgam prepared as directed in the last article is to be applied to it with a pencil, made of a piece of flattened wire fixed in a handle.

This pencil is to be occasionally dipped in the quickening, and the amalgam touched with it; a small quantity will thus adhere to the pencil, and when rubbed upon the work, will spread or flow in an instant over every part which has been touched with the quickening. The mercury is next to be driven off, by holding the article in a pair of iron pincers over a charcoal fire, till it change from a white to a gold colour; but as the mercury is apt to flow, during this process, more to one part of the article than another, it must be spread with a brush made of soft hog's hair. After the mercury is completely driven off, the article will have a dull scarfy appearance, but upon being rubbed with a small brush, made of fine brass wire, previously dipt in small beer or ale grounds, it will assume a polished surface.

Observation.—A mixture of copper and brass is the metal most commonly employed for this kind of gilding. Silver may also be gilt in the same manner; but pure copper, iron, and steel, does not take the amalgam.

ON THE CAUSE OF RAIN.

Every one must have noticed an obvious connexion between heat and the vapour in the atmosphere. Heat promotes evaporation, and contributes to retain the vapour when in the atmosphere, and cold precipitates or condenses the vapour. But these facts do not explain the phenomenon of rain, which is as frequently attended with an increase as with a diminution of the temperature of the atmosphere.

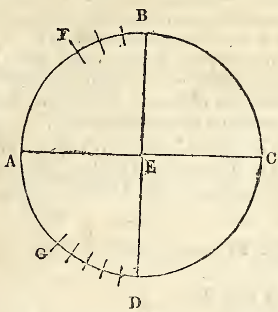
The late Dr. Hutton, of Edinburgh, is generally allowed to be the first person who published a correct notion of the cause of rain. (See Edin. Trans. vol. i. and ii. and Hutton's Dissertations, &c.) Without deciding whether vapour be simply expanded by heat, and diffused through the atmosphere, or chemically combined with it, he maintained from the phenomena that the quantity of vapour capable of entering into the air increases in a greater ratio than the temperature; and hence he fairly infers, that whenever two volumes of air of different temperatures are mixed together, each being previously saturated with vapour, a precipitation of a portion of vapour must ensue, in consequence of the *mean* temperature not being able to support the *mean* quantity of vapour.

The cause of rain, therefore, is now no longer an object of doubt. If two masses of air of unequal temperatures, by the ordinary currents of the winds, are intermixed, when saturated with vapour, a precipitation ensues. If the masses are under saturation, then less precipitation takes place, or none at all, according to the degree. Also the warmer the air, the greater is the quantity of vapour precipitated in like circumstances. Hence the reason why rains are heavier in summer than winter, and in warm countries than in cold.

SOLUTION OF QUESTIONS.

QUEST. 21, *answered by* F. *of Manchester, (the proposer).*

Let ABCD be the wheel whose circumference is divided into 60 buckets, F the



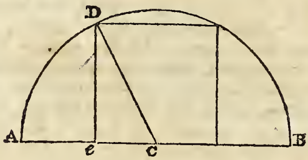
third bucket from B, and the first that the water enters from the perpendicular B E; G the fifth bucket from D, and the distance at which the water leaves the wheel from the perpendicular E D.

Then $\frac{1200 \times 14553}{60} = 291060$ cubic inches of water expended every minute; and $\frac{291060}{10 \times 60} = 485{\cdot}1$ inches of water in each bucket. Then the specific gravity of an inch of water being ·036169, we have $036169 \times 485{\cdot}1 = 17{\cdot}54558$ lbs. the weight of water in each bucket.

Now $360^\circ \div 60 = 6^\circ$ the arc or distance between the centre of each bucket on the wheel; then (per mechanics) if the natural cosine of the several arcs accounted from A, viz. $6^\circ \cdot 12^\circ \cdot 18^\circ \cdot 24^\circ$, &c. both ways towards B and D, be multiplied severally into the weight of water in each bucket, the sum of the whole will be 311·27042 lbs. the equilibrium power when applied to the circumference at A, as required.

Quest. 26, *answered by* C. N. F.

Let A D B be the semicircle,



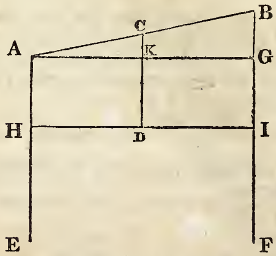
then put $a = AB$, $x = De$, consequently $\frac{a}{2} = CD$, and $\frac{x}{2} = Ce$; and (by Euclid 47·1) $CD^2 = De^2 + Ce^2$, or $x^2 + \frac{x^2}{4} = \frac{a^2}{4}$ or, $x^2 = \frac{a^2}{5}$ and $x = \frac{a}{\sqrt{5}}$ the side of the square.

This question was answered nearly in the same manner, by Mr. J. Holroyd, teacher at Oldham; by a Mechanic at Bury; by Mr. John Barr, Somers Town; and by the Proposer, who employed the well-known property of the circle demonstrated by Euclid, in his 35th prop. B 3; but the above solution is rather shorter.

This question was also solved by Mr. Richard Graham, Teacher, Liverpool; and by Master James O'Reilly, Portsea.

Quest. 27, *answered by a* Mechanic *of Bury*.

Let A and B



be the points from which the perpendiculars are to be let fall, and D the point through which the straight line is to be drawn. Join the points A and B, and bisect the line A B in C, also join C and D, and draw the indefinite lines A E and B F parallel to C D. From A let fall the perpendicular A G on B F, and through D draw H I parallel to A G. And H I will be the line required.

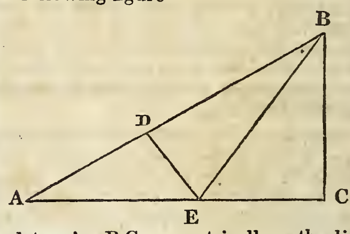
Demon. A G is perpendicular to B F, but C D is parallel to B F; therefore A K is perpendicular to C K, and in the triangle A G B, we have (Euclid 2·6) C A : A K :: B A : A G. But B A is bisected in C, therefore A G is bisected in K, and therefore A K = K G. But A D and K I are parallelograms; hence, A K = H D = K G = D I. Whence the two perpendiculars let fall from A and B, viz. A H and B I, cut off equal segments, H D and D I, from the point D. Q. E. D.

This question admits of a much simpler solution, and Mr. Holroyd, *of Oldham*, employed it in the solution he sent us, but we insert the above on account of its originality.

QUESTIONS FOR SOLUTION.

Quest. 31, *proposed by a* Mechanic, *of Bury*.

Given the lines A D, D E, and A E, in the following figure



to determine B C geometrically,—the line B D being supposed equal to B E, and the angle at C a right angle.

Quest. 32, *proposed by* Mr. S. A. Hart, *Student of the Royal Academy*.

A painter had fixed a ladder so that the upper end touched the top front of a house, and the bottom of the ladder was twelve feet from the street door; and having occasion to lower the top four feet, he found, that the bottom end extended double that quantity beyond the former position: required the height of the building and length of the ladder?

Quest. 33, *proposed by* An Original.

What is the area of the space inclosed by four shillings placed in the form of a square, each shilling being ·925 of an inch in diameter?

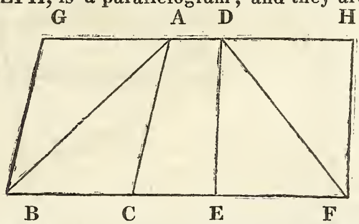
GEOMETRY.

PROPOSITION XXXVIII.

Theorem.—*Triangles upon equal bases, and between the same parallels, are equal to one another.*

Let the triangles A B C, D E F be upon equal bases B C, E F, and between the same parallels B F, A D: the triangle A B C is equal to the triangle D E F.

Produce A D both ways to the points G, H, and through B draw B G parallel to C A, and through F draw F H parallel to E D: then each of the figures GBCA, DEFH, is a parallelogram; and they are



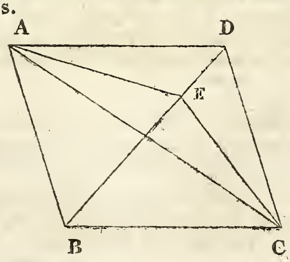
equal to one another, because they are upon equal bases B C, E F, and between the same parallels B F, G H; and the triangle A B C is the half of the parallelogram GBCA, because the diameter A B bisects it; and the triangle D E F is the half of the parallelogram DEFH, because the diameter D F bisects it: but the halves of equal things are equal; therefore the triangle ABC is equal to the triangle DEF. Wherefore triangles, &c. Q. E. D.

Cor. Hence, if the base B C be greater than the base E F, the triangle A B C will be greater than the triangle E D F; and if B C be less than E F, the triangle A B C will be less than the triangle EDF. Also, if the triangle ABC be greater than EDF, then is B C greater than E F; and if less, less.

PROPOSITION XXXIX.

Theorem.—*Equal triangles upon the same base, and upon the same side of it, are between the same parallels.*

Let the equal triangles A B C, D B C, be upon the same base B C, and upon the same side of it; they are between the same parallels.

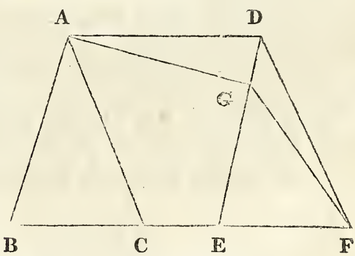


Join AD; A D is parallel to B C; for, if it is not, through the point A draw A E parallel to BC, and join E C: the triangle A B C is equal to the triangle E B C, because it is upon the same base B C, and between the same parallels B C, A E: but the triangle A B C is equal to the triangle B D C; therefore also the triangle B D C is equal to the triangle E B C, the greater to the less, which is impossible: therefore A E is not parallel to B C. In the same manner, it can be demonstrated, that no other line but A D is parallel to B C; A D is therefore parallel to it. Wherefore equal triangles upon, &c. Q. E. D.

PROPOSITION XL.

Theorem.—*Equal triangles upon equal bases, in the same straight line, and towards the same parts, are between the same parallels.*

Let the equal triangles A B C, D E F, be upon equal bases B C, E F, in the same straight line B F, and towards the same parts; they are between the same parallels.

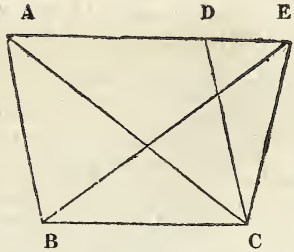


Join A D; A D is parallel to B C: for, if it is not, through A draw A G parallel to B F, and join G F. The triangle ABC is equal to the triangle GEF, because they are upon equal bases B C, E F, and between the same parallels B F, A G: but the triangle ABC is equal to the triangle DEF; therefore also the triangle DEF is equal to the triangle GEF, the greater to the less, which is impossible: therefore A G is not parallel to B F: and in the same manner it can be demonstrated, that there is no other parallel to it but A D; A D is therefore parallel to B F. Wherefore equal triangles, &c. Q. E. D.

PROPOSITION XLI.

Theorem.—*If a parallelogram and a triangle be upon the same base, and between the same parallels; the parallelogram is double of the triangle.*

Let the parallelogram ABCD and the triangle EBC be upon the same base B C, and between the same parallels B C, A E; the parallelogram ABCD is double of the triangle EBC.



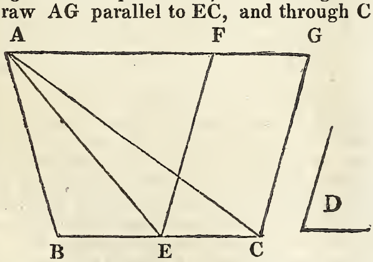
Join AC; then the triangle ABC is equal to the triangle EBC, because they are upon the same base BC, and between the same parallels BC, AE. But the parallelogram ABCD is double of the triangle ABC, because the diameter AC divides it into two equal parts; wherefore ABCD is also double of the triangle EBC. Therefore, if a parallelogram, &c. Q. E. D.

PROPOSITION XLII.

Problem.—*To describe a parallelogram that shall be equal to a given triangle, and have one of its angles equal to a given rectilineal angle.*

Let ABC be the given triangle, and D the given rectilineal angle. It is required to describe a parallelogram that shall be equal to the given triangle ABC, and have one of its angles equal to D.

Bisect BC in E, join AE, and at the point E in the straight line EC make the angle CEF equal to D; and through A draw AG parallel to EC, and through C

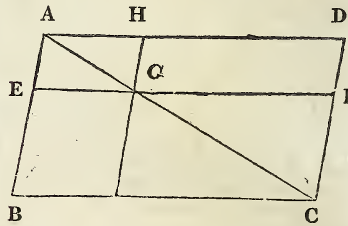


draw CG parallel to EF: therefore FECG is a parallelogram: and because BE is equal to EC, the triangle ABE is likewise equal to the triangle AEC, since they are upon equal bases BE, EC, and between the same parallels BC, AG; therefore the triangle ABC is double of the triangle AEC. And the parallelogram FECG is likewise double of the triangle AEC, because it is upon the same base, and between the same parallels: therefore the parallelogram FECG is equal to the triangle ABC, and it has one of its angles CEF equal to the given angle D. Wherefore there has been described a parallelogram FECG equal to a given triangle ABC, having one of its angles CEF equal to the given angle D. Which was to be done.

PROPOSITION XLIII.

Theorem.—*The complements of the parallelograms which are about the diameter of any parallelogram, are equal to one another.*

Let ABCD be a parallelogram, of which the diameter is AC; let EH, FG be the parallelograms about AC, that is, through which AC passes, and let BK, KD be the other parallelograms, which make up the whole figure ABCD, and are therefore called the complements: the complement BK is equal to the complement KD.



Because ABCD is a parallelogram, and AC its diameter, the triangle ABC is equal to the triangle ADC: and, because EKHA is a parallelogram, and AK its diameter, the triangle AEK is equal to the triangle AHK: for the same reason, the triangle KGC is equal to the triangle KFC. Then, because the triangle AEK is equal to the triangle AHK, and the triangle KGC to the triangle KFC; the triangle AEK, together with the triangle KGC, is equal to the triangle AHK, together with the triangle KFC: but the whole triangle ABC is equal to the whole ADC; therefore the remaining complement BK is equal to the remaining complement KD. Wherefore, the complements, &c. Q. E. D.

PROPOSITION XLIV.

Problem.—*To a given straight line to apply a parallelogram, which shall be equal to a given triangle, and have one of its angles equal to a given rectilineal angle.**

Let AB be the given straight line, and C the given triangle, and D the given rectilineal angle. It is required to apply to the straight line AB a parallelogram equal to the triangle C, and having an angle equal to D.

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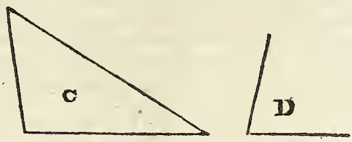
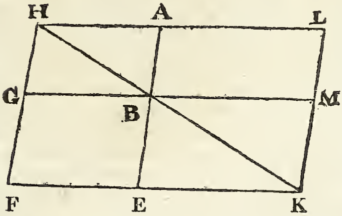
* To apply a parallelogram to a straight line, means to form it upon that line, or to make that line one of its sides.

In this proposition we are to describe a parallelogram with the two conditions required in the 42d proposition, and also one more, namely, "to apply a parallelogram to a given straight line."

Make the parallelogram BEFG equal to the triangle C, having the angle EBG



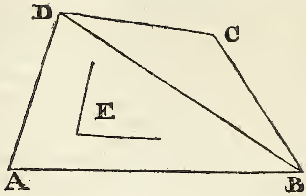


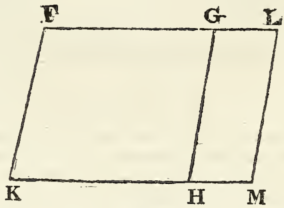
equal to the angle D, and the side BE in the same straight line with AB: produce FG to H, and through A draw AH parallel to BG or EF, and join HB. Then because the straight line HF falls upon the parallels AH, EF, the angles AHF, HFE, are together equal to two right angles; wherefore the angles BHF, HFE are less than two right angles: but straight lines which with another straight line make the interior angles, upon the same side, less than two right angles, do meet if produced far enough: therefore HB, FE will meet, if produced; let them meet in K, and through K draw KL parallel to EA or FH, and produce HA, GB to the points L, M: then HLKF is a parallelogram, of which the diameter is HK; and AG, ME are the parallelograms about HK; and LB, BF are the complements; therefore LB is equal to BF: but BF is equal to the triangle C; wherefore LB is equal to the triangle C; and because the angle GBE is equal to the angle ABM, and likewise to the angle D; the angle ABM is equal to the angle D: therefore the parallelogram LB is applied to the straight line AB, is equal to the triangle C, and has the angle ABM equal to the angle D: which was to be done.

PROPOSITION XLV.

Problem.—*To describe a parallelogram equal to a given rectilineal figure, and having an angle equal to a given rectilineal angle.*

Let ABCD be the given rectilineal figure, and E the given rectilineal angle. It is required to describe a parallelogram equal to ABCD, and having an angle qual to E.





Join DB, and describe the parallelogram FH equal to the triangle ADB, and having the angle HKF equal to the angle E; and to the straight line GH apply the parallelogram GM equal to the triangle DBC, having the angle GHM equal to the angle E. And because the angle E is equal to each of the angles FKH, GHM, the angle FKH is equal to GHM; add to each of these the angle KHG; therefore the angles FKH, KHG are equal to the angles KHG, GHM; but FKH, KHG are equal to two right angles; therefore also KHG, GHM are equal to two right angles: and because at the point H in the straight line GH, the two straight lines KH, HM, upon the opposite sides of GH, make the adjacent angles equal to two right angles, KH is in the same straight line with HM. And because the straight line HG meets the parallels KM, FG, the alternate angles MHG, HGF are equal; add to each of these the angle HGL; therefore the angles MHG, HGL, are equal to the angles HGF, HGL: but the angles MHG, HGL, are equal to two right angles, wherefore also the angles HGF, HGL are equal to two right angles, and FG is therefore in the same straight line with GL. And because KF is parallel to HG, and HG to ML, KF is parallel to ML; but KM, FL are parallels; wherefore KFLM is a parallelogram. And because the triangle ABD is equal to the parallelogram HF, and the triangle DBC to the parallelogram GM, the whole rectilineal figure ABCD is equal to the whole parallelogram KFLM; therefore the parallelogram KFLM has been described equal to the given rectilineal figure ABCD, having the angle FKM equal to the given angle E. Which was to be done.

Cor. From this it is manifest how to apply a parallelogram to a given straight line, which shall have an angle equal to a given rectilineal angle, and shall be equal to a given rectilineal figure; viz. by applying to the given straight line a parallelogram equal to the first triangle ABD, and having an angle equal to the given angle.

The enunciation of this proposition is *general*, though the truth of it is here illustrated by employing a *four-sided* figure. If the given figure consist of five, six, &c. sides, it will only be necessary to construct a parallelogram for every triangle that the figure is divided into.

MECHANICS.

ON FRICTION.

Having finished our description of the simple mechanical powers, the next branch of the science of mechanics, which naturally falls to be considered, is that of friction.

The word *friction* properly signifies the act of one body rubbing upon another; but in mechanics it is employed to denote the degree of retardation, or of obstruction to motion, which arises from one surface rubbing upon another. If we place a heavy body upon a surface perfectly level, it is not in a state of equilibrium between all the forces which act upon it, otherwise it would move by the application of the smallest force, in a direction parallel to the plane. Its friction upon the level surface is the unbalanced force, which occasions this want of perfect equilibrium; and if a new force, of equal magnitude, is applied so as to balance that force in any given direction, the body will obey the least impulse in that direction, and the force thus employed will be an exact measure of the retarding force of friction. "Friction," as Mr. Playfair has justly remarked, "destroys, but never generates motion, and in this is unlike gravity, or any of the forces hitherto considered, which, if they retard motion in one direction, always accelerate it in the opposite. The force of friction, therefore, violates the law of continuity, and cannot be accurately expressed by any geometrical line, or any algebraic formula." Though friction destroys motion, and generates none; it is of essential use in mechanics. It is the cause of stability in the structure of machines, and is necessary to the exertion of the force of animals. A nail, or screw, or a bolt, could give no firmness to the parts of a machine, or of any other structure, without friction. Animals could not walk, or exert their force any how, without the support which it affords. Nothing could have any stability but in the lowest possible situation; and an arch, which could sustain the greatest load, when properly distributed, might be thrown down by the weight of a single ounce, if not placed with mathematical exactness at the very point which it ought to occupy.

As a knowledge of the nature and effects of friction, and of the method of diminishing its influence in machinery, is of the first importance in practical mechanics, we shall offer no apology for making a few observations on the subject.

The subject of friction has occupied the particular attention of many distinguished individuals, particularly Amontons, Bulfinger, Parent, Euler, and Bossut; but though their writings contain much important information, and many ingenious views, yet it was reserved for the celebrated Coulomb, to give an accurate and satisfactory investigation of this difficult branch of practical mechanics. By using bodies of a large size, he has corrected the errors of preceding writers, and discovered many new and valuable facts, which had escaped the notice of his predecessors.

In treating of this important subject, we shall consider it under the following heads.

The Friction of Surfaces. The Friction of Axles. The Friction and Rigidity of Ropes. The Friction of Pivots; and, the Means of diminishing Friction in Machinery.

ON THE FRICTION OF SURFACES.

There are two general modes of examining the nature and effects of friction.

The first, ascertains the weight required to draw a body under the pressure of a given load along the horizontal surface of another.

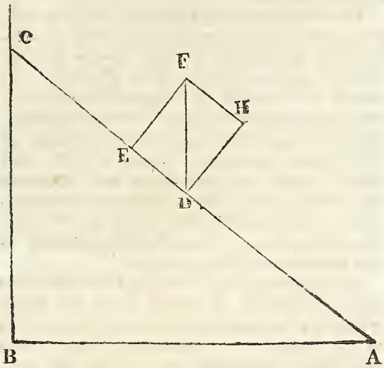
The second method is still simpler, and consists merely in raising the end of the upper plane, till it acquires the inclination at which the load it bears begins to slide. The angle or inclination at which this motion commences, is called the angle of *equilibrium*.

In examining the friction of surfaces, M. Amontons found, that it was exactly proportional to the weight of the moving or rubbing body, and was in general equal to *one-third* of the weight with which it was pressed against the surface over which it moved. He found also, that the resistance did not increase with an increase of the rubbing surfaces, nor with the velocity of the body.

M. Bulfinger obtained results nearly similar to those of Amontons, but he made the resistance of friction equal only to *one-fourth* of the force, with which the rubbing surfaces are pressed together.

M. Parent, considering friction as caused by small spherical eminences in one surface, being dragged out of small spherical cavities in the other, proposed to determine the quantity of friction by finding the force, which would move a sphere standing upon three equal spheres. This force he found to be to the weight of the sphere as 7 to 20, or to be $\frac{1}{2 \cdot 855}$ of the sphere's weight.

In his experiments on friction, M. Parent employed the second of the above methods; that is, he placed the body upon an inclined plane, as represented in the following figure.



Here CA represents the position of the plane, at the moment the load begins to slip; and if the vertical FD represent the weight, FE will express the perpendicular pressure sustained by the plane, and OED must denote the corresponding friction, which, in this instance, is just balanced by the tendency to descend. Wherefore, the pressure is to the friction, as FE to ED, or as AB to BC, that is, as radius to the tangent of the angle of repose.

These two modes of experimenting, however, will seldom give precisely the same results. Most bodies require a greater force to pull them from their contact, than what is afterwards sufficient to maintain their adhesive motion. But the obliquity of the plane evidently marks only the initial obstruction, and not the diminished friction which afterwards follows.

Thus, if the plane CA were a pine board, upon which is laid a block of oak with a smoothed surface, it may be elevated to an acclivity of 30 degrees before it disengages its load. But should the angle of declination exceed only 10 degrees, on striking the side with a smart blow, the oaken block will start from its seat, and then glide downwards. While the plane retains this lower position, the load will not rest on being again replaced, unless it be held in contact a few seconds.

The celebrated Euler considered the ratio between *friction* and the force of *pressure*, to be as 1 to 4; and observes, that when a body is in motion, the friction will be only one-half of what it is when the body has begun to move, and he shows, that if we gradually augment the inclination of an inclined plane, till the body which is placed upon it begins to descend, the friction of the body at the commencement of its motion will be to its pressure against the plane, as the height of the plane to its length. But when the body is in motion, the friction is diminished, and may be found by calculation.*

The Abbe Bossut has distinguished friction into two kinds; viz. that which is generated by one surface rubbing upon another, and that which arises from one body turning or rolling upon another. The circumference of a wheel rolling on the ground is an example of the first of these, and the friction of the axle of a wheel in motion is a combination of the two kinds of friction. M. Bossut agrees with Amontons in his opinion, that an increase of surface does not occasion an increase of friction. He took a rectangular parallelopiped of wood, weighing 51 lbs. and having dragged it over a horizontal table, and loaded it with different weights, he found, that though one of its surfaces was *five* times greater than the other, the same force was capable of putting the body in motion, whether it rested on the large or the small base. Muschenbroek, and other writers, maintained, that the friction increased with the surface.

Bossut has remarked two very important facts on the subject of friction; namely, that the friction is affected by the time in which the surface remains in contact, and that it does not follow exactly the ratio of the pressures. He found, that when the surfaces had been for some time in contact, their friction increased, either in consequence of a greater number of eminences having entered into the corresponding cavities from a continuance of the pressure, or from some physical cause, which united the two surfaces more firmly together. Bossut likewise noticed, that in large masses the friction is a less part of the pressure than in small masses; but he does not seem to have observed, that this arose from the greater velocity, which the mass derived from its magnitude. "Shipbuilders," he observes, "give only a declivity of from 10 to 12 lines in a foot to the inclined planes upon which vessels are launched. But this declivity, which is sufficient for putting large masses in motion in spite of the resistance of friction, is too small for weights of a moderate size." Bossut, however, seems to have suspected, that friction might diminish as the velocity increased, when he says, "that if it happens on one hand, that in proportion as the velocity increased, there are more points

* He has given a formula for this purpose, but we consider it too intricate to be inserted here.

to disengage, or more springs to bend; yet it may happen, on the other hand, that this same velocity does not give to the pressure time to permit the points to enter the cavities so deeply as they would be allowed to do if the velocity were less. But a diminution of this depth ought to produce a diminution of friction."

Coulomb also made a number of interesting experiments on this subject, from which he has drawn the following general conclusions.

1. The friction of wood upon wood, when ungreased, occasions, after a sufficient period of contact, a resistance proportional to the pressure. This resistance increases sensibly in the first instants of repose, but after some minutes it generally reaches its maximum.

2. When wood, ungreased, moves upon wood, with any velocity whatever, the friction is still proportional to the pressure, but its intensity is much less than that which is experienced in detaching the surfaces after some minutes of rest. The force, for example, which is necessary to detach two surfaces of oak after some minutes of rest, is to that necessary for overcoming the friction when the surfaces have already any degree of velocity whatever, nearly as 9·5 to 2·2.

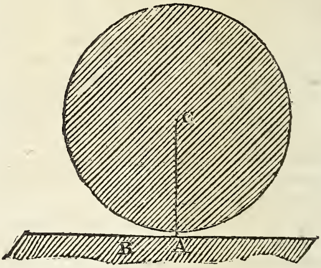
3. The friction of metals sliding over metals, ungreased, is also proportional to the pressures, but its intensity is the same, whether the surfaces detached have been any time at rest, or whether they have received any uniform velocity whatever.

4. Heterogeneous substances, such as those of woods and metals, sliding upon one another without grease, give for their friction very different results from the preceding; for the intensity of their friction relative to the time in which they have continued in contact increases slowly, and does not reach its maximum till after four or five days, and sometimes more, whereas in metals, it reaches its maximum in an instant, and in wood, after a few minutes. This increase is even so slow, that the resistance of friction in insensible velocities is nearly the same as that which takes place in moving or detaching the surfaces after three or four seconds of rest. In the motion of wood rubbing upon wood without grease, and in metals moving upon metals, the velocity has very little influence upon the friction; but, in the present case, the friction increases very sensibly, in proportion as we increase the velocities; so, that the friction increases nearly in arithmetical progression, as the velocities increase in geometrical progression.

When a cylinder is made to *roll* upon a plane surface, it encounters a new sort of obstruction, quite distinct in its character, and generally much inferior to that of sliding friction. These different kinds of friction are strikingly contrasted, in the rolling and sliding of different cylinders of wood down inclined planes. These cylinders will not begin to *slide* lengthwise, though disengaged by percussion, unless the slope of the plane exceed 10 degrees; but they will *roll* easily at much smaller angles.

The inclination of 4 degrees will be sufficient to enable a cylinder of elm, of one inch in diameter, to roll down an oak board, and an angle of 3 degrees will cause a cylinder of lignum-vitæ of the same dimensions to roll. But a single degree of slope will make an elm cylinder of four inches diameter begin to roll, and three fourths of that angle will occasion the rolling of a like cylinder of lignum-vitæ. The loss of force in the act of rolling is therefore inversely proportional to the diameter of the cylinder.

If adhesion were confined to the mere line of contact, it could have no effect whatever in hindering the revolving motion of a cylinder, on a horizontal plane. But this power, subsisting an instant after contact has taken place, may be conceived as constantly drawing it down at a certain distance behind. Thus, if A



be the contact of the cylinder, and B the point where the adhesion is mainly exerted, its efficacy to restrain the rolling of the cylinder will evidently be as A B to A C. On the supposition that A B is constant, this retarding force is inversely as the radius A C; that is, the greater the diameter of the cylinder, the less is the friction. In the case of elm, the distance A B must be the 28th part of an inch; but in lignum-vitæ it is only the 40th part.

ON THE FRICTION OF AXLES.

The principal object of Coulombe in his experiments on this subject, was to determine the friction of the axles of machines in motion.

He employed axles of iron moving in boxes of brass. One of these was 19 lines in diameter, and had a play of 1¼ lines in the brass box.* The pulley in which the axle was fixed was 144 lines in diameter, and its weight 14 pounds. The weights were made to run through a space of six feet, and the time employed to run through the first and last three feet was separately measured in half-seconds. In this way he made a very great number of experiments, and obtained a number of important results, which our limits will not permit us to mention.

Coulomb likewise extended his experiments to the friction of axles made of the different kinds of wood used in rotatory machines. For this purpose he used pulleys of 12 inches in diameter, with axles three inches in diameter. The axles were sometimes moveable and at other times fixed, though in both cases the friction was the same. The levelling surfaces were carefully smoothed.

Names of the Wood used for the Axles.

	Ratio of Friction to pressure.	
1. Axis of holm oak running in a box of lignum vitæ coated with tallow	0,038	$\frac{1}{26 \cdot 3}$
2. Do. the coating of tallow wiped off, and the surface remaining greasy . . .	0,06	$\frac{1}{16 \cdot 7}$
3. Do. after being used several times without renewing the tallow	0,06 0,08	$\frac{1}{16 \cdot 7}$ $\frac{1}{12 \cdot 3}$
4. Do. running in a box of elm coated with tallow . .	0,03	$\frac{1}{33 \cdot 3}$
5. Do. both axis and box wiped and the surfaces remaining greasy	0,05	$\frac{1}{20}$
6. Do. axis of boxwood, and box of lignum vitæ, coated with tallow	0,043	$\frac{1}{23}$
7. Do. the coating wiped, and the surfaces remaining greasy	0,07	$\frac{1}{14 \cdot 3}$
8. Axis of box-wood and box of elm, coated with tallow .	0,035	$\frac{1}{28 \cdot 6}$
9. Do. the coating wiped off, and the surfaces remaining greasy	0,05	$\frac{1}{20}$
10. Axis of *iron*, and box of lignum vitæ, the coating wiped off, and the pulley turned for some time . .	0,05	$\frac{1}{20}$

In these experiments the velocity did not appear to influence the friction unless in the first instants of rest; and in all cases the friction was least when the surfaces were merely greasy, and not coated with tallow.

* A line is one-twelfth of an inch.

In *Wheeled Carriages*, the draught is facilitated by three distinct circumstances.

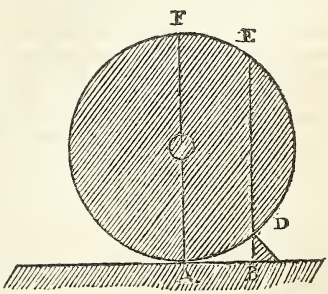
1. The excessive obstruction which the rim of the wheel would encounter if dragged along the road, is changed to the very inferior friction of the axle against the bush of the nave.

2. This reduced friction has its influence, in impeding the progress of the carriage, still farther diminished, in the ratio of the diameter of the wheel to that of the axle.

3. The dimensions of the wheel enable it to surmount easily any obstacle which may occur; the effect being the same as if it were drawn over an inclined plane, from its point of contact to the top of the eminence.

The friction of the rim of a locked wheel, even on the smoothest road, might perhaps exceed the half of the whole load; but the friction of the axle in its box, which is substituted for it, would amount only to the eighth part, when *iron* is inserted in a copper bush, and scarcely to the seventh part when oak turns in lignum vitæ, the grease in both cases being worn smooth. The power of this friction within the nave, in retarding the motion of the carriage, must be directly as the diameter of the axle, and inversely as the height of the wheel. A large wheel and a small axle are therefore the most advantageous. For this reason, an *iron* axle, though it has twice as much friction as an *oak* one of the same dimensions, may be preferred for its smallness. In carriages rightly fitted and carefully greased, the whole friction seldom exceeds the *thirtieth*, but need not amount to the *sixtieth* part of the load.

To assign the force expended in overcoming an obstacle, let the wheel, represented by the following figure, touch A the horizontal line of traction;

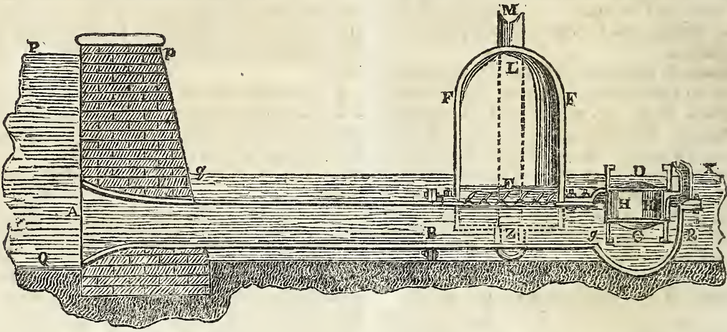


if it meet a protuberance B D, it must be lifted over this with the progressive motion A B: the draught is therefore to the load, as A B to B D. Large wheels are therefore best adapted, not only for diminishing the effect of friction, but for surmounting the inequalities of the road.

HYDRAULICS.

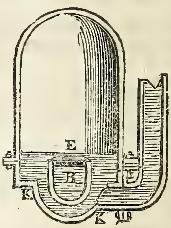
MONTGOLFIER'S HYDRAULIC RAM.

This interesting machine was first constructed by Montgolfier about the year 1797, and has been brought to a very perfect state, by a series of improvements which he has successively made upon it. The rams represented by the following figures, contain the improvements which have been made so late as 1816.



The large pipe A B, called the body of the ram, passes through the side of the reservoir P Q, from which the fall of water is obtained. It has a trumpet mouth at one end A, and at the other end an opening H H, which can be closed by valves C or D. When these valves are open, the water will issue at H H with a velocity due to the height A P; but when the internal valve C is closed, as in the figure, the water is prevented from issuing. When the valve C opens, it descends into the position shown by the dotted lines G G, being guided between three or four stems *g g*, which have hooks at the lower ends for supporting the valves. In this case the water has a free passage between these stems, and the width of the passage can be increased or diminished, by the screws with which the stems are fixed. The valve C is made of metal, and has a hollow cup or dish of metal attached to its lower surface. The seat H H of the valve is wider than the diameter of the pipe AB. It consists of a short cylinder or pipe screwed by its flanch *h h*, into the opening of the upper surface of the head R of the ram; and the cylinder is so formed, as to have an inverted cup or annular space *i i* round the upper part of it for containing air, which cannot escape when it is compressed by the water. A small pipe *k l*, leading from this annular space to the open air, is furnished with small valves *k*, *l*, one of which, *k*, opens inwards to admit the air into *i*, *i*, but to prevent its return; while the other valve, *l*, admits a certain quantity of air, and then shuts and prevents any farther entrance. The valve D is exactly the same as C, only it descends as in the figure when it shuts, and rises when it opens.

The upper part of the head of the ram at E is made flat, and has several valves, which allow the water to pass freely from the pipe A B, but prevent its return. On each side of the head of the ram, at the part opposite to these valves, is a hollow enlargement, shown by the dotted lines K, forming a circular basin, through the centre of which the pipe A B R passes. This part of the construction is shown more distinctly in the following figure,



which is a transverse section through L E Z, in a plane perpendicular to that of the paper. The pipe is here made flat instead of circular, for forming the seats of the valves, and the basin K K is covered with an air vessel F F. This air vessel communicates all round the pipe B, with the basin K K, and with the vertical pipe M.

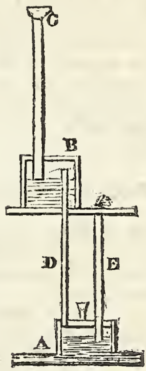
The machine being thus constructed, let us suppose the pipe ABR full of water, and the valve C to be opened, the water will lift the valve D, and escape with a velocity due to the height of the reservoir. In a short time, the water having acquired an additional velocity, raises the valve G, which shuts the passage, and prevents the escape of the water. The consequence of this is, that all the included water exerts suddenly a hydrostatical pressure on every part of the pipe, compressing at the same time the air in the annular space *i i*, which, by its elasticity, diminishes the violence of the shock. This hydrostatical pressure opens the valves at E, and a portion of the water flows into the air vessel F, and condenses the air which it contains. The valves at E now close, preventing the return of the water into the pipe, and the water recoils a little in the tube, with a slight motion from B to A, in consequence of the reaction or elasticity of the compressed air in *i i*, and also of the metal of the pipe, which must have yielded a little to the force exerted upon it in every direction. The recoil of the water towards A produces a slight aspiration within the head R of the ram, which causes the valve D to descend by its own weight, and prevent the water X, which covers it, from descending into the tube. The air, however, passes through the pipe *l k*, opens the valve *k*, and a small quantity is sucked into the annular space *i i*; but the quantity is very small, as the valve *k* closes as soon as the current of air becomes rapid. During the recoil towards A, the valve C, being unsupported, falls by its own weight; and when the force of recoil is expended, by acting on the water in the reservoir P Q, the water begins again to flow along A B R, and the very same operation which we have described is repeated without end, a portion of water being driven into the air vessel F, at every ascent of the valve C. The air in this vessel being thus highly compressed, will exert a force due to its elasticity upon the surface of the water in the vessel F, and will force it up through the pipe M, to a height which is sufficient to balance the elasticity of the included air.

The small quantity of air, which is drawn into the annular space *i i* through the air tube *l k* at each aspiration, causes an accumulation of air in the space *i i;* and when the aspiration of recoil takes place, a small quantity of air passes from *i i*, and proceeds along the pipe till it arrives beneath the valve at E, and lodging in the small space beneath the valves, it is forced into the air vessel at the next stroke, and thus affords a constant supply of air to the vessel. The valves make in general from 50 to 70 pulsations in a minute.

When the fall of water, or PQ, is five feet, and the pipe AB six inches in diameter, and 14 feet long, a machine with its parts proportioned, as in the figure, will raise water to the height of 100 feet. It will expend about 70 cubic feet per minute in working it, and will raise about $2\frac{1}{3}$ cubic feet per minute to the height of 100 feet. Mr. Millington observes, that one of these machines is said to have raised 100 hogsheads of water in 24 hours, to the height of 134 feet, by a fall of $4\frac{1}{2}$ feet.

SCHEMNITZ FOUNTAIN, OR HUNGARIAN MACHINE.

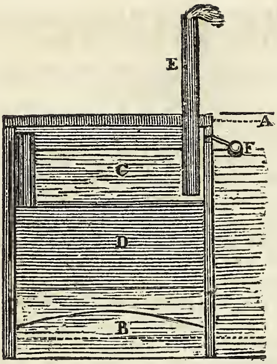
A portion of air is employed for raising water, not only in the spiral pump, but also in the air vessels of Schemnitz. A colum of water, descending through a pipe into a closed reservoir, full of air, obliges the air to act, by means of a pipe, leading from the upper part of the reservoir or air vessel, on the water in a second reservoir, at any distance either below or above it, and forces this water to ascend through a third pipe to any height less than that of the first column. The air vessel is then emptied, and the second reservoir filled and the whole operation is repeated.



Thus the reservoir A being filled with water, and B with air, and water being poured into the funnel C, the air in B acts by the pipe D on the water in A, and forces it up the pipe E.

The air must, however, acquire a density equivalent to the pressure, before it can begin to act; so that if the height of the columns were 34 feet, it must be reduced to half its dimensions before any water would be raised; and thus half of the force would be lost; in the same manner, if the height were 68 feet, two thirds of the force would be lost. But where the height is small, the force lost in this manner is not greater than that which is usually spent in overcoming friction and other imperfections of the machinery employed; for the quantity of water, actually raised by any machine, is not often greater than half the power which is consumed.

The force of the tide, or of a river rising and falling with the tide, might easily be applied by a machine of this kind, to the purposes of irrigation, as represented by the following figure.

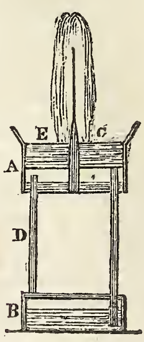


Thus, A being the high water mark, and B the low water mark, the vessels C and D are filled at high water from below, the air being suffered to escape by a stop-cock, which is opened by the fall of the ball F; at low water, the air will enter the vessel D at B; and before the next high water, the water C will be forced up the pipe F.

FOUNTAIN OF HIERO.

The Fountain of Hiero precisely resembles in its operation, the Schemnitz fountain, which was probably suggested to its inventor by that of Hiero.

The first reservoir of this fountain is lower than the orifice of the jet; and a pipe descends from it to the air vessel, which is at some distance below, and the pressure of the air is communicated by an ascending tube to a third cavity, containing the water which supplies the jet. The following figure will convey an idea of this fountain without any particular description of its several parts, for it so nearly resembles the Schemnitz fountain in its operation, that this becomes unnecessary, except perhaps to state, that the pipe D here ascends.



WATER RAISED BY THE CHANGES IN THE WEIGHT OF THE AIR.

The spontaneous changes which take place in the pressure of the air, occasioned by the changes in the weight and temperature of the atmosphere, have been applied, by means of a series of reservoirs, furnished with proper valves, to the purpose of raising water by degrees to a moderate height. But it very seldom happens, that such changes are capable of producing an elevation in the water of each reservoir of more than a few inches, or at most a foot or two in a day; consequently, the whole quantity raised in this way must be very inconsiderable.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF THE LATE PROFESSOR PLAYFAIR, OF EDINBURGH.

John Playfair, a celebrated Scotch mathematician and natural philosopher, was the eldest son of the Rev. James Playfair, minister of the united parishes of Liff and Benvie, in the county of Forfar. He was born at Benvie, on the 10th of March, 1748; and after receiving a classical education under the roof of his father, he entered the university of St. Andrews at the age of fourteen. At this ancient seat of learning, Mr. Playfair soon distinguished himself by the excellence of his conduct, as well as the ardour of his application; and so great was his progress in natural philosophy, that Professor Wilkie, (the author of the *Epigoniad)* who taught that branch of knowledge in the university, selected him to teach his class during his indisposition.

In the year 1766, upon the death of Mr. Stewart, Professor of Mathematics in Marischal College, Aberdeen, seven candidates appeared for the vacant chair. Among these were the Rev. Dr. Trail, Dr. Hamilton, and Mr. Playfair. The professorship was a private foundation, by Dr. Liddel, and a clause in the deed of foundation was considered as a direction to fill up the vacancy by a disputation or comparative trial. Dr. Reid, of Glasgow, Mr. Vilant, of St. Andrews, Dr. Skene, of Marischal College, and Professor Gordon, of King's College, accepted the office of judges on this occasion; and after a severe examination, which lasted for a fortnight, Dr. Trail was appointed to the chair. Mr. Playfair was excelled only by two out of six candidates; viz. Dr. Trail and Dr. Hamilton; but when it is considered, that Mr. Playfair was two years younger than Dr. Trail, the result of the election must have been greatly affected by that circumstance alone; and Dr. Trail himself modestly remarked, that he attributed his own success to this disparity of years.

In the year 1772, when the chair of natural philosophy became vacant by the death of Dr. Wilkie, Mr. Playfair again cherished the hopes of a permanent appointment; but his expectations were a second time frustrated; a disappointment which was the more severe, as the death of his father in the same year had devolved upon him the charge of his mother and her family. This circumstance appears to have determined Mr. Playfair to follow the profession of his father, to which he had been educated, but which his ardent attachment to mathematical pursuits had induced him to think of abandoning. Having been presented by Lord Gray to his father's living of Liff and Benvie, Mr. Playfair devoted his time to the duties of his sacred office, to the education of his younger brothers, and to the occasional prosecution of his own favourite studies. In 1774 he went to Schehallien, where Dr. Maskelyne was carrying on his interesting experiments on the attraction of mountains; and while he was enjoying the acquaintance of that eminent astronomer, he was little aware that he should himself contribute, at some distant period, to the perfection of the result which it was the object of this experiment to obtain.

In the year 1777, Mr. Playfair communicated to the Royal Society of London, an essay *On the Arithmetic of Impossible Quantities,* which appeared in the Transactions for that year, and which was the first display of his mathematical acquirements. In this ingenious paper, which is strongly marked with the peculiar talent of its author, Mr. Playfair has pointed out the insufficiency of the explanation of the doctrine of negative quantities given by John Bernouilli and Maclaurin; viz. that the imaginary characters which are involved in the expression compensate or destroy each other; and he has endeavoured to show that the arithmetic of impossible quantities is nothing more than a particular method of tracing the affinity of the measures of ratios and of angles, and that they can never be of any use as an instrument of discovery, unless when the subject of investigation is a property common to the measures both of ratios and of angles.

In the year 1785, when Dr. Adam Ferguson exchanged the chair of Moral Philosophy in the University of Edinburgh, for that of Mathematics, which was then filled by Mr. Dugald Stewart, Mr. Playfair was appointed Joint Professor of Mathematics, a situation which had been the highest object of his ambition, and which he was in a peculiar manner qualified to fill.

As Mr. Playfair was a member of the Philosophical Society of Edinburgh, he became one of the original fellows of the Royal Society at its institution by royal charter in 1783, and, by his services as an office-bearer, as well as by his communications as a member, he contributed most essentially to promote the interests, and to add to the renown, of this distinguished body. His memoir *On the Causes which affect the accuracy of Barometrical Measurements*, was read on the 1st of March, 1784, and on the 10th January, 1785. The mensuration of heights by the barometer was involved in many errors. M. De Luc had applied the important correction, depending on the temperature of the atmospherical column; but when the height was great, and the difference of temperature at the two extremities of the column considerable, his method of estimating the temperature was liable to considerable error. Mr. Playfair was therefore led to give an accurate formula for this purpose, and to investigate new ones, in order to express those other circumstances by which the density of the atmosphere is affected.

Mr. Playfair was also the author of several other valuable papers, among which may be mentioned the following: On the Origin and Investigation of Porisms; Remarks on the Astronomy of the Brahmins; Investigation of certain Theorems relative to the Figure of the Earth; On Volcanoes; On the progress of Heat, when communicated to Spherical Bodies; On the Solids of greatest Attraction; a subject to which his attention was directed during a lithological survey of the mountain of Schehallien, which he made in conjunction with Lord Webb Seymour, in 1807, for the purpose of obtaining an estimate of the specific gravity of the mountain, in order to correct the deductions of Dr. Maskelyne, respecting the mean density of the earth.

Mr. Playfair was also the author of some very able pamphlets on the memorable Leslie controversy, which took place on the appointment of Mr. Leslie to the Professorship in the University of Edinburgh, in 1805.

In the year 1795, Mr. Playfair published his *Elements of Geometry*, which consisted of the first six books of Euclid, with three additional ones, containing the rectification and quadrature of the circle, the intersection of planes, and the geometry of solids, with plane and spherical trigonometry, and the arithmetic of sines. The notes to this work possess a peculiar value; and hence the work itself has been held in high estimation for the purposes of elementary instruction.

After five years' labour, Mr. Playfair produced, in 1802, his *Illustrations of the Huttonian Theory*, in one volume 8vo.; and on the 10th January, 1803, he read to the Royal Society of Edinburgh his *Biographical Account of the late Dr. James Hutton*. These two works added greatly to the fame of their author; and whether we consider them as models of composition or of argument, we cannot but regard them as the productions by which the name of Mr. Playfair must be handed down to posterity. Though brought out under the modest appellation of a commentary, it is unquestionably entitled to be regarded as an original work; and though the theory which it expounds must always retain the name of the philosopher who first suggested it, yet Mr. Playfair has in a great measure made it his own, by the philosophical generalizations which he has thrown around it; by the numerous phenomena which he has enabled it to embrace; by the able defences with which its weakest parts have been sustained; and by the relations which he has shown it to bear to some of the best established doctrines, both in chemistry and astronomy.

Upon the death of Dr. Robison, in 1805, Mr. Playfair was elected General Secretary to the Royal Society, and he was also appointed his successor in the chair of natural philosophy,—a situation which his mathematical acquirements, and his powers of perspicuous illustration, rendered him peculiarly qualified to fill. This event, however, though in every respect advantageous to himself, interrupted in no slight degree the progress of his general studies. The preparation of a course of lectures on subjects which he had only indirectly pursued, and the composition of his Outlines of Natural Philosophy, which he considered necessary for the use of his students, occupied much of that valuable time on which the higher interests of science possessed so many claims.

In addition to the works which bear Mr. Playfair's name, he wrote various articles in the *Edinburgh Review*, which he never hesitated to acknowledge, and some of which have been reprinted among his works. Of these reviews, *three* are particularly memorable, as indicating the peculiar character of Mr. Playfair's talents, as well as the great versatility of his powers. His analysis of the *Mécanique Céleste* of Laplace, while it evinces the highest powers of composition, is at the same time one of the choicest specimens of perspicuous illustration. His review of *Leslie's Geometry* (the ablest, perhaps, that he ever wrote) is distinguished by a masterly argument in one of the most difficult topics of abstract mathematics, and has been no less celebrated for the force and the dignity of its satire.* The review of Madame de Stael's *Corinne* in the same work, affords the clearest evidence that its author was equally fitted to shine in the field of elegant literature and in the walks of abstract science. Several other reviews from Mr. Playfair's pen would have been entitled to notice in a more extended memoir of his life, but those already mentioned have been selected as particularly characteristic of his powers as a natural philosopher, a profound mathematician, and a cultivator of the lighter branches of literature.

At the restoration of peace in 1815, Mr. Playfair undertook a journey to the Continent, for the purpose of examining the stupendous phenomena presented in the geology of the Alps,—of studying the recent effects of volcanic eruptions in Italy, and of developing those of more ancient convulsions among the extinct volcanoes of Auvergne. Excepting the phenomena exhibited in our own island, which he had personally examined, Mr. Playfair had acquired his geological knowledge principally from books; and it was therefore desirable, before the republication of his favourite work, that his views should receive those modifications which the study of nature in her grandest forms could not fail to suggest. With this view he spent about seventeen months in France, Switzerland, and Italy, busily engaged in geological observations; and he returned to Edinburgh in the end of 1816, eager to embellish and complete the great fabric which it had been the business of his life to rear.

Unfortunately, however, for the Huttonian School, Mr. Playfair had been urged to draw up a dissertation on the progress of mathematics and physics for the Supplement to the Encyclopædia Britannica; and the composition of this paper, interrupted the execution of the second edition of his Illustration.

His health, had been for some time on the decline; and in the winter of 1818—1819, his labours were often interrupted by a severe attack of a disease in the bladder, which, at his advanced period of life, it was not easy to subdue. An interval of health soothed for a while the anxieties of his friends; but it was only a deceitful precursor of the fatal attack which carried him off, on the 19th July, 1819, in the 72d year of his age.

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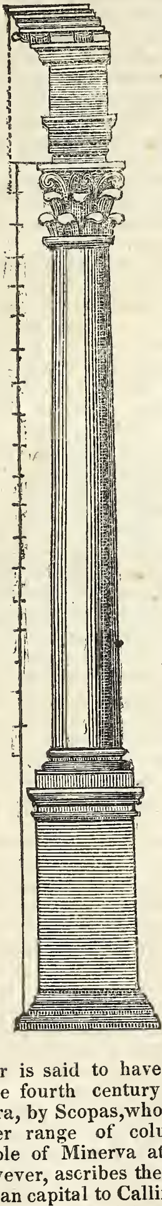
* M. Legendre, one of the first of modern geometers, has, both privately and publicly, expressed his particular admiration of this criticism.

ARCHITECTURE.

CORINTHIAN ORDER.



This order is said to have been introduced in the fourth century before the Christian æra, by Scopas, who employed it in the upper range of columns in the ancient temple of Minerva at Tega. Vitruvius, however, ascribes the invention of the Corinthian capital to Callimachus, who is said to have been an Athenian sculptor contemporary with Phidias about 540 B.C.

In all the examples of Stuart's Athens, this order has an attic base; the upper fillet of the trochilus or scotia projects as far as the upper torus.

Vitruvius observes, that the shaft has the same proportions as the Ionic, except the difference which arose from the greater height of the capital, it being a whole diameter; whereas the Ionic is only two-thirds of it. But this column, including the base and capital, has, by the moderns, been increased to *ten* diameters in height. If the entablature is enriched, the shaft should be fluted. The number of flutes and fillets are generally 24; and frequently the lower one-third of the height has cables or reeds, husks, spirally twisted ribbands, or some sort of flowers inserted on them.

The great distinguishing feature of this order is its *capital*, which has for 2000 years been acknowledged the greatest ornament of this school of architecture. The height is *one* diameter of the column, to which the moderns have added *one-sixth* more. The body, or nucleus, is in the shape of a bell, basket, or vase, crowned with a quadrilateral abacus, with concave sides, each diagonal of which is equal to two diameters of the column. The lower part of the capital consists of two rows of leaves, eight in each row; one of the upper leaves fronting each side of the abacus. The height of each row is one-seventh, and that of the abacus one-eighth of the whole height of the capital. The space which remains between the upper leaves and the abacus, is occupied by little stalks, or slender caulicolæ, which spring from between every two leaves in the upper row, and proceed to the corners, and also to the middle of the abacus, where they are formed into delicate volutes. The sides of the abacus are moulded, and the curves of the sides are continued, until they meet in a sharp horn or point. In the attic capital, the small divisions of the leaves were pointed in imitation of the acanthus. In Italy they most generally resembled the olive.

It may be observed generally, in the Greek Corinthian, that the volutes terminate in a point in the natural spiral, without either coiling round a circular eye, or bending backwards in a serpentine form, as in most of the Roman specimens.

This order seems never to have been much employed in Greece before the time of the Roman conquest; but this powerful people employed it almost exclusively in every part of their extensive empire; and it is accordingly in edifices constructed under their influence, that the most perfect specimens are found.

Of the celebrated modern architects who have treated of this order, Palladio makes the column $9\frac{1}{2}$ diameters high, one-fifth of which he gives to the entablature, consisting of a cornice with modillions and dentils, a flat frieze, and an architrave with three faciæ, divided by astrigals; the base is attic. The design of Scammozzi bears a general resemblance to that of Palladio, but his column has ten diameters in its altitude; his entablature is one-fifth of this height; the cornice has modillions, the architrave consists of three faciæ, divided by astragals, and the base is attic. Serlio, following Vitruvius, has given this order an Ionic entablature, with dentils, and the same proportion of the capital; his column is nine diameters high, and has a Corinthian base. Vignola's Corinthian is a grand and beautiful composition, chiefly imitative of the three columns. He makes the column ten diameters and a half in height; the entablature is a fourth of that altitude; the cornice has modillions and dentils, the frieze is plain, the architrave of three faciæ, divided by mouldings, and the base is attic.

Sir William Chambers has observed, that "the Corinthian order is proper for all buildings where elegance, gaiety, and magnificence are required. The ancients employed it in temples dedicated to Venus, Flora, Proserpine, and the nymphs of fountains; because the flowers, foliage, and volutes, with which it is adorned, seemed well adapted to the delicacy and elegance of such deities."

ON THE IMPRACTICABILITY OF PRODUCING A PERPETUAL MOTION.

Perpetual *motion*, is a motion which is supplied and renewed from itself, without the intervention of any external cause: to find a *perpetual* motion, or to construct a machine which shall have such a motion, is a subject which has engaged the attention of mathematicians for more than two thousand years; though none, perhaps, have prosecuted it with so much zeal and hopes of ultimate success as some of the speculative philosophers of the present age.

Infinite are the schemes, designs, plans, engines, wheels, &c. to which this longed-for *perpetual* motion has given birth; and it would not only be endless but ridiculous to attempt to give a detail of them all, especially as none of them deserve particular mention, since they have all equally proved abortive; and it would rather partake of the nature of an affront than a compliment, to distinguish the pretenders to this discovery; as the very attempting of the thing conveys a very unfavourable idea of the mental powers of the operator.

For among all the laws of matter and motion we know of none, which seems to afford any principle or foundation for such an effect. *Action* and *reaction* are allowed to be ever equal; and a body which gives any quantity of motion to another, always loses just so much of its own: but, under the present state of things, the resistance of the air, and the friction of the parts of machines, necessarily retard every motion.

To keep the motion going on, therefore, there must either be a supply from some foreign cause; which, in a *perpetual* motion, is excluded:

Or, all resistance from the friction of the parts of matter must be removed; which necessarily implies a change in the *nature of things*.

For, by the second law of motion, the changes made in the motions of bodies are always proportional to the impressed moving force, and are produced in the same direction with it; no motion, then, can be communicated to any engine, greater than that of the first force impressed.

But, on our earth, all motion is performed in a resisting fluid; namely, the atmosphere, and must therefore, of necessity, be retarded: consequently, a considerable quantity of its motion will be spent on the medium. Nor is there any engine or machine wherein all friction can be avoided; there being in nature no such thing as exact smoothness, or perfect congruity: the manner of the cohesion of the parts of bodies, the small proportion which the solid matter bears to the vacuities between them, and the nature of those constituent particles, not admitting it.

Friction, therefore, will also in time sensibly diminish the impressed or communicated force; so that a *perpetual* motion can never follow, unless the communicated force be so much greater than the generating force, as to supply the diminution occasioned by all these causes: but the generating force cannot communicate a greater degree of motion than it had itself. Therefore, the whole affair of finding a *perpetual* motion, comes to this; viz, to make a weight *heavier* than *itself*, or an elastic force *greater* than *itself:* or, there must be some method of gaining a force equivalent to what is lost, by the artful disposition and combination of the mechanical powers: to this last point, then, all endeavours are to be directed; but how, or by what means, such a force can be gained, is still a mystery!

The multiplication of powers or forces avails nothing: for what is gained in *power*, is lost in *time;* so that the quantity of motion still remains the same.

The whole science of Mechanics cannot really make a little power equal or superior to a larger; and wherever a less power is found in equilibrio with a greater, as for example, twenty-five pounds with a hundred, it is a kind of deception of the sense: for the equilibrium is not strictly between one hundred pounds and twenty-five pounds, but between one hundred pounds, and twenty-five pounds moving, (or disposed to move,) *four times as fast* as the one hundred.

A power of ten pounds, moving with ten times the velocity of one hundred pounds, would have equalled the one hundred in the same manner; and the same may be said of all the possible products equal to one hundred: but, there must still be one hundred pounds of power on each side, whatever way they may be taken; whether in matter, or in velocity.

This is an inviolable law of nature; by which nothing is left to art, but the choice of the several combinations that may produce the same effects.

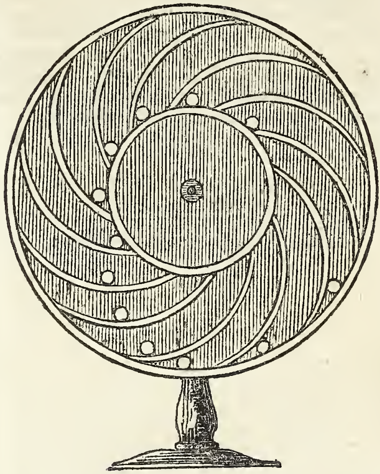
The only interest that we can take in the projects which have been tried for procuring a *perpetual motion*, must arise from the opportunity that they afford of observing the *weakness of human reason.*

For a better instance of this can scarcely be supplied than to see a man spending whole years in the pursuit of an object, which a single *week's* application to sober philosophy would have convinced him was unattainable.

But for the satisfaction of those who may not be convinced of the impossibility of attaining this grand object, we shall add a few observations on the subject of a still more practical nature than the above.

The most satisfactory confutation of the notion of the possibility of a perpetual motion, is derived from the consideration of the properties of the centre of *gravity;* it is only necessary to examine whether it will begin to *descend* or *ascend*, when the machine moves, or whether it will remain at rest. If it be so placed, that it must either remain at rest or ascend, it is clear, from the laws of equilibrium, that no motion derived from gravitation can take place: if it may descend, it must either continue to descend for ever with a finite velocity, which is impossible, or it must first descend and then ascend, with a vibratory motion, and then the case will be reducible to that of a *pendulum*, where it is obvious, that no *new* motion is generated, and that the *friction* and *resistance* of the *air* must soon destroy the *original* motion.

One of the most common fallacies, by which the superficial projectors of machines for obtaining a perpetual motion have been deluded, has arisen from imagining, that any number of weights ascending by a certain path, on one side of the centre of motion, and descending in the other, at a greater distance, must cause a constant preponderance on the side of the descent: and for this purpose weights have been made to slide or roll along groves or planes, which lead them to a more remote part of the wheel from whence they return as they ascend, as represented in the following figure,*



or they have been fixed on *hinges*, which allow them to fall over at a certain point, so as to become more distant from the centre; but it will appear on the inspection of such a machine, that although some of the weights are more distant from the centre than others, yet there is *always* a proportionally smaller number of them on that side on which they have the greater power; so that these circumstances precisely counterbalance each other.

We have heard it proposed to attach hollow arms to a wheel by joints or hinges at the circumference, and to fill these arms with *quicksilver*, or small balls, instead of the plan represented by the above figure; but though we have never heard of it having been tried, we are perfectly convinced, that it would end as all other attempts have done; that is, in a total failure.

SOLUTION OF QUESTIONS.

QUEST. 25, *answered by* MR. A. PEACOCK, *St. George's East.*

The figure of the stone may be reckoned a prismoid, the arches being but a small part of a large circle will have but a trifling difference from the chords.

First $76 + 5 = 81$ the greater diameter, and $81 : 3\frac{1}{3} :: 76 : 3 \cdot 127572$ the least breadth; then $3\frac{1}{3} \times 4 = 13\frac{1}{3}$ area of the greater end;

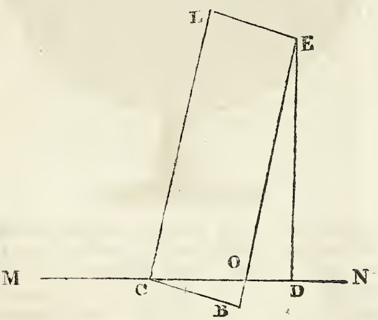
* In the model, the balls may be kept in their places by a plate of glass covering the wheel.

and $3{\cdot}127572 \times 4 = 12{\cdot}510288$ area of the lesser end; then,
$3\frac{1}{3} + 12{\cdot}510288 \div 2 = 12{\cdot}921810$ mean area, therefore, $3\frac{1}{3} + 12{\cdot}510288 + \overline{12{\cdot}921810 \times 4} = 77{\cdot}53086$, which multiplied by $\frac{5}{6} =$ 64·60905 solid feet the content of the stone; and as one solid foot of Portland stone weighs 2570 ounces, $64{\cdot}60905 \times 2570 = 166045\frac{1}{4}$ ounces = 4 tons, 12 cwt, 2 qrs. 17 lb, $13\frac{1}{4}$ oz. the weight of the stone.

This question was also answered correctly by Mr. H. Flather, the proposer; but he neglected to find the *weight* of the stone, after determining its solid content.

Quest. 28, *answered by* Master James O'Reilly, *Portsea.*

Let C B E L represent the tower:



from E (the top of it) let fall the perpendicular E D. Then by the hypothesis, D O = 16, B O = 6 and therefore E O = 182. Now, since the angles C B O, O D E are right angles, and the angles at O equal, the triangles C B O, O D E are equiangular; therefore, D O : E O :: B O : C O;

or $16 : 182 :: 6 : 68{\cdot}25 = CO$;

but $\sqrt{CO^2 - OB^2} = CB$; therefore

$CB = \sqrt{(68{\cdot}25)^2 - (6)^2} = 67{\cdot}985$ the diameter.

This question was also solved by the proposer, and by Mr. R. Graham, *Teacher,* Liverpool.

In the above solution the tower is supposed to be cylindrical.

Quest. 29, *answered by* Mr. Whitecombe, *Teacher of Mathematics,* Cornhill.

Put $a = 3{\cdot}14159$ $m = {\cdot}5236$, and let x = diameter of the globe; then pr. mensuration ax^2 = convex surface, and mx^3 = solidity. Therefore, pr. question $ax^2 = mx^3$, then $\div$ by x^2 we have $a = mx$. Hence, $x = \frac{a}{m} = 6$ as Required.

This question was answered by so many other Correspondents, that we cannot find room to insert their names; we may, however state, that the gentlemen who solved the following question were among the number.

Quest. 30, *answered by* Mr. J. Millward, *Hammersmith.*

The longest line that can be drawn in a cube is the diameter of the circumscribing sphere, or, the diagonal of a plane that cuts the cube, by passing through the diagonals of two of its opposite planes; and the square of the side or face of the cube is one-third of the square of that line.

Therefore, if the diameter of a cube be 9 inches, $\sqrt{9^2 \div 3} = 5{\cdot}1961524$ = the side of the cube; and $(5{\cdot}1961524)^3 = 140{\cdot}296113573$ = the solidity of the cube. Which was required.

This question was also solved by the following gentlemen: Mr. J. Snart, *Tooley-street;* Mr. R. Graham, *Liverpool;* Master James O'Reilly, *Portsea;* M. J. Whitecombe, *Cornhill;* Mr. A. Peacock, *St. George's East;* Mr. J. Stephens; Mr. John Barr, *Somers Town;* Mr. J. Holroyd, *Oldham;* C. N. S.; and by the Proposer.

QUESTIONS FOR SOLUTION.

Quest. 34, *proposed by* I. C. S. *Church-row.*

Suppose the neck of the hollow glass ball (see Artisan, Expt. 5, page 69) to be immersed in water, and the air to be extracted out of *it* and the *receiver* which covers it: required how much rarer was the air within the receiver before admitting the air from without, and how much *water* it forced into the *ball,* supposing the diameter of the water's surface when forced into the ball to be 7·2, and its height from the top of the ball to be 1·8 of an inch?

Quest. 35, *proposed by* Mr. R. Graham, *Liverpool.*

There is a globe of cast-iron one foot diameter, and a conical piece of *dry oak* six feet in length on the side of the prince's dock, Liverpool; required the diameter of the cone's base when the globe is fixed to the vertex of the cone and put into the dock at full tide, where it floats with its surface just level with the water?

Quest. 36, *proposed by* G. G. C.

Required how much higher than the cross of St. Paul's must a person be elevated, in order to see the top of the Eddystone Lighthouse?

PNEUMATICS.

STEAM ENGINE.

Having given a description and representation of the steam engines of Savery and Newcomen, (see page 195,) and also of the double stroke engine of the late celebrated Mr. Watt, we shall now begin to give a particular description of its principal parts, previous to noticing some of those engines for which patents have been more recently obtained. But it will tend very much to render a description of the several parts of this master-piece of human skill more easily understood, to give a short account of the alterations and improvements made upon it by Mr. Watt, and this we cannot do better than by quoting a part of that excellent engineer's patent.

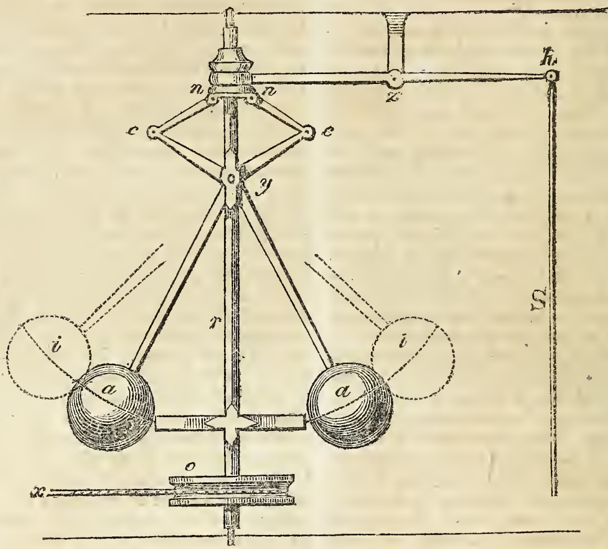
"My method of lessening the consumption of steam, and consequently fuel in fire engines," says Mr. Watt, in the specifications of his patent, "consists of the following principles. First, that vessel in which the powers of steam are to be employed, to work the engine, which is called the cylinder in common fire engines, and which I call the steam vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it; first, by inclosing it in a case of wood, or any other materials that transmit heat slowly; secondly, by surrounding it with steam, or other heated bodies; and thirdly, by suffering neither water, nor any other substance colder than steam, to enter or touch it during that time. Secondly, in engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels *distinct* from the steam vessels, or cylinder, although occasionally communicating with them; these vessels I call *condensers;* and, whilst the engines are working, these condensers ought at least to be kept as cold as the air, in the neighbourhood of the engines, by application of water, or other cold bodies. Thirdly, whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam vessels, or condensers, by means of pumps wrought by the engines themselves, or otherwise. Fourthly, I intend, in many cases, to employ the expansive force of steam to *press* on the *pistons*, or whatever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire engines: in cases where cold water cannot be had in plenty, the engines may be wrought by this force of steam only, by discharging the steam into the open air after it has done its office. Fifthly, where motions *round* an *axis* are required, I make the steam vessels in form of hollow rings, or circular channels, with proper inlets and outlets for the steam, mounted on horizontal axles like the wheels of a water mill; within them are placed a number of valves, that suffer any body to go round the channel in one direction only; in these steam vessels are placed weights, so fitted to them as entirely to fill up a part or portion of their channels, yet capable of moving freely in them by the means hereinafter mentioned or specified. When the steam is admitted in these engines, between the weights and the valves, it acts equally on both, so as to raise the weight to one side of the wheel, and, by the reaction of the valves, successively, to give a *circular motion* to the wheel, the valves opening in the direction in which the weights are pressed, but not in the contrary; as the steam vessel moves round, it is supplied with steam from the boiler, and that which has performed its office may either be discharged by means of condensers, or into the open air. Sixthly, I intend, in some cases, to apply a degree of cold, not capable of reducing the steam to water, but of contracting it considerably, so that the engines may be worked by the alternate expansion and contraction of the steam. Lastly, instead of using water to render the piston or other parts of the engines air and steam tight, I employ oils, wax, resinous bodies, fat of animals, quicksilver, and other metals, in their fluid state."

The term of this patent was prolonged by act of parliament until the year 1799; but although the legal privilege of the original manufacturers expired, yet the superiority of their workmanship still gave their engines a decided preference to others. It was found, that their engines saved three-fourths of the fuel formerly used; and that only one-fourth of the whole force of the steam was wasted. One of these engines, with a thirty inch cylinder, performs the work of 120 horses, working 8 hours each, per day.

In order to regulate the varying quantity of steam, which was produced by the different states of the fire under the boiler, and admitted into the cylinder, Mr. Watt thought of several methods; but the one generally employed is to place a valve in the pipe connecting the boiler and the cylinder, which is made to increase or diminish the passage for the steam. This valve is called a throttle-valve, and is made to act of itself, and also made to admit of being so adjusted as to admit less steam into the cylinder, when the piston is moving with too great velocity, and to admit a greater quantity when it is moving too slowly.

The attached balls marked W, (see the figure, page 197), and called a lift-tenter, were employed by Mr. Watt to regulate the opening and shutting of the throttle-valve.

Thus in the annexed figure



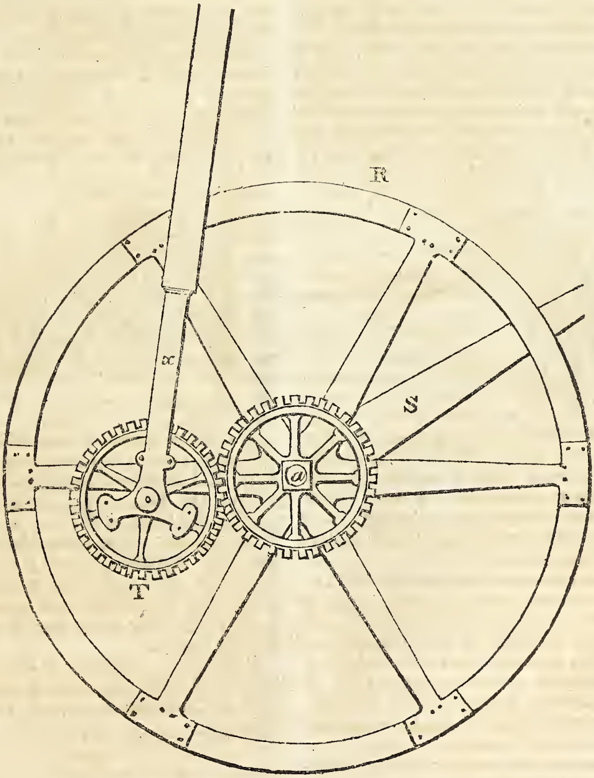
a, a are the two balls attached to an upright spindle by a joint, and connected with the throttle-valve by a series of small levers resting on a pivot *z*. *x* is an endless chain or cord going round a pully *o*, which is fixed to the vertical stem *r*, and retained in that position by moving in sockets at *z* and *y*. *a, a*, are two balls fixed to levers having a moveable joint at *y:* these levers are bent after their junction, in the position shown in the figure, and are connected by another joint at *c, c*, to two short levers fixed by a joint at *n, n*, to a broad ring or strap of metal moving freely up and down on the vertical spindle. On this ring or strap, the ends of a lever *z* formed like a fork, are made to fit it; the lever is suspended at *z* and has another joint at *h*, by which it is connected with the rod S, which is attached to the axis of the throttle-valve. When the piston is moving with its usual velocity, the balls, being connected by the endless rope *x*, revolve and hang in the situation as shewn in the figure. But should the velocity of the piston be much increased, its motion will be communicated by the rope and pulley to the spindle *r*, and the balls will, by their centrifugal force, rise into the situation shewn by the dotted lines *i, i;* this will depress the ends of their levers at *c, c*, and also the end of the horizontal lever which is attached to the moveable ring; and the rod S, will be raised, which closes in part, the steam way. Should the motion of the piston be too slow, instead of *rising*, the balls will *fall*, and have quite a contrary operation on the levers and throttle-valve; and diminish the quantity of steam admitted into the cylinder.

By these and other contrivances, having made the reciprocating motion of his engines very regular, Mr. Watt early turned his attention to the important object of producing a continuous rotatory motion from a reciprocating one.

"Among the many schemes," says Mr. Watt, "which passed through my mind, none appeared so likely to answer the purpose as the application of a crank in the manner of a common turning lathe, (an invention of great merit, of which the humble inventor and even its era are unknown); but as the rotative motion is produced in that machine by the impulse given to the crank in the descent of the foot only, and is continued in its ascent by the momentum of the wheel, which here acts as a fly; and being unwilling to load my engine with a fly heavy enough to continue the motion during the ascent of the piston (and even were a counterweight employed to act, during the ascent, of a fly heavy enough to equalize the motion) I proposed to employ two engines, acting upon two cranks, fixed on the same axis at an angle of 120 degrees to one another, and a weight placed on the circumference of the fly at the same angle to each of the cranks, by which means a motion might be rendered nearly equal, and a very light fly would only be requisite."

In order to obtain a *rotatory* motion from a rectilineal one by some other means than the crank, Mr. Watt introduced what is now called the Sun and Planet Wheels: it is also a cardioid motion, and has several advantages over the crank, where a more rapid movement is to be given to the fly; the fly being made to revolve with double the velocity as when a crank is employed. It is not, however, so simple, and its construction makes it more expensive, besides it is easily put out of order, and has now given place to the crank.

We shall, however, give a short description of these wheels, as they are sometimes employed in other machines. In the annexed figure



x, is an arm attached to the lever, or working beam; and S, the axis which imparts motion to the machinery. The wheel T, is fixed to x, and the wheel S, on the axis of R; and both wheels are fixed as nearly as possible in the same vertical plane. On the rising and falling of the working beam, the wheel T, is carried round the circumference of the wheel S, and at the instant when the motion of the lever is reversed, the continuous rotatory movement is produced by the momentum of the fly-wheel.

In order to ascertain the elasticity or expansive force of the steam remaining in the condenser, Mr. Watt adapted a barometer tube filled with mercury, to the condenser. The mercury in this tube is acted upon nearly in the same manner, as the mercury in the common barometer by the atmosphere: and if a perfect vacuum were produced in the condenser, the mercury in the tube would stand at the same height as in the common barometer; but as a perfect vacuum is never produced, the mercury in the tube rises to a height corresponding to the degree of elasticity possessed by the steam, and shows the force with which the atmospheric air presses on the mercury to enter the condenser. A similar tube, called the *Steam-Gauge*, was fixed on the boiler which indicated, by the ascent and descent of the mercury, the elasticity of the steam, and consequently shows the force with which the steam presses upon the boiler, in order to make its escape, when its temperature exceeds 212 degrees. At a less temperature than this, it will stand at the same degree as the condenser gauge.

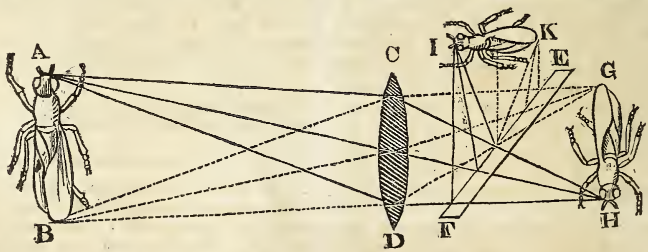
OPTICS.

CAMERA OBSCURA.

The *camera obscura*, or the *dark chamber*, is a name given to a very amusing optical instrument invented by Baptista Porta.

If a room be made entirely dark, and a convex lens of one or more feet focal length be placed in a small hole in the window shutter, it will form behind it, on a sheet of white paper, a beautiful picture of all the objects before it, in which will be seen all those movements and changes of colour and of position, which characterize the living picture without.

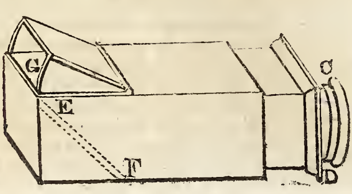
In order, however, to have this picture formed upon a horizontal surface for the purpose of copying it, the rays proceeding from it must be received upon a plane mirror, inclined to the horizon at an angle of 45°, as shown in the following figure:



where A B is the object without the window, C D the lens, G H the image that would be formed upon a vertical sheet of paper if the plane mirror E F were not interposed, and I K the image formed upon a plate of ground glass whose rough surface is placed uppermost.

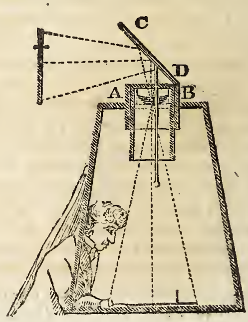
The picture may then be traced with great accuracy on the surface of the ground glass. But if it be required to throw the image upon a sheet of white paper, we have only to conceive the whole inverted, and E F placed a little nearer to C D, in order to throw I K to a greater distance, and leave room for the introduction of the hand of the artist between E and K.

The foregoing figure represents the construction of the *portable camera obscura*, the outside of which is exhibited by the following figure:



It consists of two square drawers, D and E F, the drawer D containing the lens at C D, and capable of being moved out or in within the tube E for the purpose of adjusting the focus of the lens to the distance of the object. The other drawer E contains the inclined mirror E F, which reflects the rays upon the ground glass G, and has a lid which turns up in order to keep off the light from the picture on the ground glass.

When it is required to draw upon the surface of paper, the camera obscura must have the form represented by the following figure,



where A B is the lens, and C D a mirror on the outside of it, which is placed in such a manner as to reflect the landscape downwards, on the ground E F. The observer places his head through an opening on one side, and introduces his hand with the pencil through another opening, so that no light whatever may be admitted at these apertures to efface the distinctness of the picture.

A camera obscura for public exhibition requires to be on a large scale; so that several persons may see it distinctly at the same time. Instruments of this kind are generally erected in public Observatories, such as that of Greenwich, Edinburgh, and Glasgow, where three very fine camera obscuras have been fitted up; but our limits will not permit us to give a description of them.

In the construction of the camera obscura, the splendour of the picture depends on various circumstances which have not hitherto been sufficiently attended to. It has been found from experience, that a common lens, is preferable to the best achromatic object glass; and Dr. Wollaston has suggested the application of the periscopic principle to the lens of the camera. M. Cauchoix has found, that the most advantageous ratio of the radii of curvature is that of 5 to 8, the shortest of the two being that which is turned towards the image.

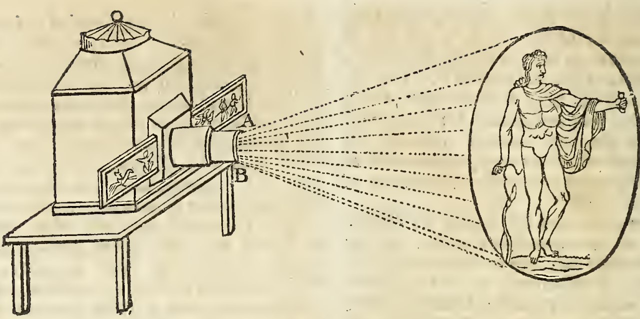
Next to the optical perfection of the image is the nature of the surface upon which it is received. When paper is employed, it should be made as smooth as possible by burnishing the surface; and when a stucco surface is used, the greatest care must be taken to remove all asperities, and make it perfectly uniform. With the view of obviating the imperfection of the ordinary opaque grounds, Dr. Brewster made a great variety of experiments. Though he did not find any white surfaces superior to those in common use, he was surprised to observe the brilliancy and distinctness with which the pictures were represented when received upon the silvered back of a looking-glass; and he gave additional perfection to the images, by removing the protuberances and roughness of the tinfoil, by carefully grinding the surface with a soft kind of bone. Notwithstanding the bluish colour of the metallic ground, while objects are represented in their true tints, and so brilliant is the colouring, and so rich the verdure of the foliage, that the image seems to surpass in beauty even the object itself. Various experiments have also been made by the same author, to discover a good *transparent surface* as a substitute for ground glass, which would permit the application of an eye-glass. The loss of light, when the image is received on ground glass is enormous. In order to prevent this, and give brilliancy to the colouring, Dr. Brewster places another plate of glass above the ground one, and introduces between them water, or any other fluid of a different refractive power from the ground glass; the dispersion of the light at the separating surface of the ground glass and the fluid being sufficient to detain the convergent pencils without greatly weakening their intensity. As such a ground, however, cannot be used for copying, he put a slightly opaque varnish upon the surface of a glass plate, and also upon thin squares of mica, and he found, that these varnishes might be marked with the finest lines of a pencil, and that an impression of the sketch might be conveyed by the slightest pressure of the hand on a piece of paper. One of the simplest and best of all the varnishes which he used was that of milk dried upon the glass, after it had been freed entirely from its butyraceous particles. The beauty and distinctness is such, that it will even admit the application of a lens to magnify the image, and when properly made, will receive the mark of a black lead pencil.

ON THE MEGASCOPE.

The name of *megascope* has been given to the camera obscura, when employed to represent, or to take copies of objects placed in front of the window, or of the lens in the portable camera obscura, and placed at a short distance from it. In this case, the image is generally received at a distance from the lens greater than that of the object; and is consequently very much magnified. By altering the distance of the object, the size of the image may be increased or diminished at pleasure; and when the object does not reflect much light, we have it in our power to illuminate it artificially. The megascope may be made to magnify as much as fifteen times with great advantage, and is an instrument of very great use in taking correct outlines or representations of natural objects, which, from their smallness or other causes, are not susceptible of being submitted to exact mensuration. The megascope may even be employed for copying plans or drawings on an enlarged or a reduced scale.

ON THE MAGIC LANTERN.

The magic lantern, an optical instrument invented by Athanasius Kircher, differs from the megascope only in the way in which it is fitted up, and in the purposes to which it is applied. It consists of a lens A B,



which forms on the wall an enlarged image of any object placed before it, and at a greater distance than its anterior principal focus. The objects used in the magic lantern, are pictures painted with transparent varnishes in the form of sliders, which move through a groove in front of the lens A B. These paintings are strongly illuminated with a lamp inclosed in a lantern, which admits no light whatever into the room excepting what passes through the lens A B. The light of the lamp is thrown in a condensed state upon the pictures by means of an illuminating lens, which is sometimes nearly hemispherical, and the illumination is still farther increased by a concave mirror, which throws back the light of the lamp, that radiates in the direction of the object. The painting on the sliders being thus strongly illuminated, a very distinct and enlarged image of it is represented on the wall according to principles already described; and the magnitude of the image will be to the magnitude of the object as their respective distances from the lens A B. Hence, the magnifying power may be diminished or increased, by bringing the white screen that receives the image either nearer to the lantern, or removing it to a greater distance. The images in the magic lantern are much improved by substituting two lenses in place of A B, having greater focal lengths than the single lens.

The magic lantern, which for a long time was used only as an instrument for amusing children and astonishing the ignorant, has recently been fitted up for the purpose of conveying scientific instruction; and is now universally used by popular lecturers on astronomy for representing the phases and the motions of the heavenly bodies, all of which are minutely painted on the sliders.

The magic lantern may be employed in almost every branch of scientific instruction, where it is desirable to give a distinct and enlarged representation of phenomena to a public class. The lecturer is thus saved the trouble of carrying about with him unwieldy diagrams, which are soon destroyed by use, and rendered unfit for their intended purpose.

CHEMISTRY.

MURIATIC ACID.

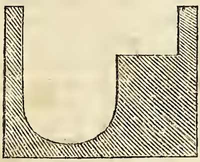
According to Dr. Thomson there are only two simple incombustible substances which unite to oxygen; viz. Azote and Muriatic Acid; the former of these has already been treated of, and the second we shall make the subject of the present article.

The *name* muriatic acid is taken from the substance which most plentifully affords it, namely, sea or marine salt, the *muria* of the Latins. This name is given to it, because its radical, or base, has not yet been discovered in nature. Before the framing of the methodical nomenclature, it was called *spirit of salt*, *marine acid*, and sometimes *acid of salt*.

The muriatic acid exists abundantly in nature in combination with common salt and the waters of the ocean. And though we are almost witnesses of this formation, we are yet unacquainted with the principles employed by nature, the proportion in which she combines them, and the mode in which the combination is effected.

Muriatic acid may be procured by the following processes:

Let a small pneumatic trough be procured, hollowed out of a single block of wood; about 15 inches long, 7 broad, and 6 deep. After it has been hollowed out to the depth of an inch, leave three inches by way of a shelf on one side, and cut out the rest to the proper depth, giving the inside of the bottom a circular form, as represented by the annexed figure*.



This trough is to be filled with mercury to the height of a quarter of an inch above the surface of the shelf. A small glass jar is then to be filled with the mercury, and placed on the shelf of the trough over one of the slits made on purpose.

The apparatus being thus disposed, two or three ounces of common salt are to be put into a small retort, and an equal quantity of sulphuric acid added; the beak of the retort plunged below the surface of the mercury in the trough, and the heat of a lamp applied to the bottom of the retort. A violent effervescence will then take place; and air bubbles will rush in great numbers from its beak, and rise to the surface of the mercury in a visible white smoke, which has a very peculiar odour. After allowing a number of them to escape, till it is supposed that the common air which previously existed in the retort has been displaced, plunge its beak into the slit in the shelf over which the glass jar has been placed. The air bubbles will soon displace the mercury and fill the jar. The gas thus obtained is called *muriatic acid gas*.

This substance in a state of solution in water was known even to the alchymists; but in a gaseous state it was first examined by Dr. Priestley, in an early part of that illustrious career in which he added so much to our knowledge of gaseous bodies.

1. Muriatic acid gas is an invisible elastic fluid, resembling common air in its mechanical properties. Its specific gravity, according to the experiments of Mr. Kirwan is 1·929, that of air being 1·000, at the temperature of 60°, barometer 30 inches; 100 cubic inches of it weigh 59·8 grains. Its smell is pungent and peculiar; and whenever it comes in contact with common air, it forms with it a visible white smoke. If a little of it be drawn into the mouth, it is found to taste excessively *acid;* much more so than vinegar.

2. Animals are incapable of breathing it; and when plunged into jars filled with it, they die instantaneously in convulsions. Neither will any combustible burn in it. It is remarkable, however, that it has a considerable effect upon the flame of combustible bodies; for if a burning taper be plunged into it, the flame, just before it goes out, may be observed to assume a green colour, and the same tinge appears next time the taper is lighted.

3. If a little of the blue coloured liquid, which is obtained by boiling red cabbage leaves and water in a tin vessel, be let up into a jar filled with muriatic acid gas, it assumes a fine red colour. This change is considered by chemists as a characteristic property of *acids;* but this will be fully treated of afterwards.

4. If a little water be let up into a jar filled with this gas, the whole gas diappears in an instant, the mercury ascends, fills the jar, and forces the water to the very top. The reason of this is, that there exists a strong affinity between muriatic acid gas and water; and whenever they come in contact, they combine and form a liquid; or, which is the same thing, the water absorbs the gas. Hence arises the necessity of making experiments with this gas over mercury. In the water cistern not a particle of gas would be procured. The water of the trough would even rush into the retort and fill it completely. It is this affinity between muriatic acid gas and water, which occasions the white smoke that appears when the gas is mixed with common air. It absorbs the vapour of water which always exists in common air. The solution of muriatic acid gas in water is usually denominated simply *muriatic acid* by chemists.

In this state it appears to have been known to the alchymists; but Glauber was the first who extracted it from common salt by means of sulphuric acid. It is prepared for commercial purposes, by mixing together one part of common salt and seven or eight parts of clay, and distilling the mixture; or by distilling the usual proportion of common salt and sulphuric acid, and receiving the product in a receiver containing water. For chemical purposes it may be procured pure in the following manner:

A hundred parts of dry common salt are put into a glass matrass, to which there is adapted a bent glass tube that passes into a small Wolf's apparatus, which is represented by the following figure.

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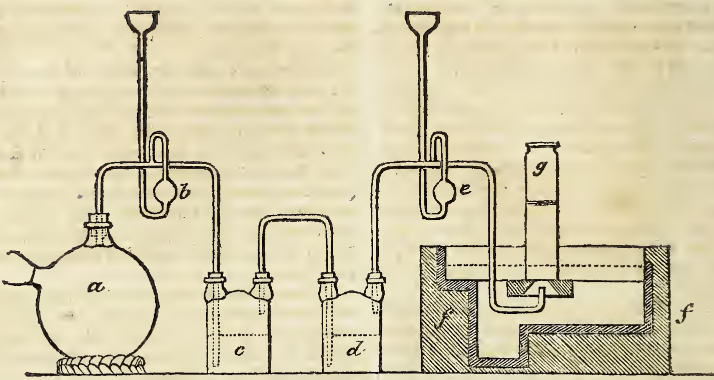
* Troughs of this kind are to be got ready made at all the shops where chemical apparatus are sold.



The first jar which is immediately connected with the receiver is employed for condensing the vapour that issues from the retort, and the first bottle contains a quantity of water equal in weight to the common salt employed, but part of the water may be put into the second bottle. When the apparatus is properly secured by luting, pour gradually through the bent tube 75 parts of sulphuric acid, or three-fourths the weight of the salt, making the additions at considerable intervals. On each effusion of the acid a large quantity of muriatic gas will pass along the bent tube, and will be absorbed by the water in the first bottle till this has become saturated; it will then pass on to the second bottle, and so on to more if they are deemed necessary.

The gas that is not absorbed by the water at its exit from the last bottle is conveyed, by means of the recurved tube, into a jar standing in a mercurial trough, as represented in the foregoing figure.

When the whole of the sulphuric acid has been added and the gas no longer issues, heat is then to be applied which will renew the production of the gas. At this period it will be necessary to keep the luting which connects the retort and receiver perfectly cool, otherwise it will be apt to melt.

When no more gas is produced, the operation may be suspended, and the liquid in the two bottles, which is muriatic acid, put into others with ground stoppers and preserved for use.

A cubic inch of water at the temperature of 60°, barometer 29·4°, absorbs 515 inches of muriatic acid gas, which is equivalent to 308 grains nearly. Hence water thus impregnated contains 0·548, or more than half its weight of muriatic acid, in the same state of purity as when gaseous. Dr. Thomson caused a current of gas to pass through water till it refused to absorb any more. The specific gravity of the acid thus obtained was 1·203. If we suppose that the water in this experiment absorbed as much gas as in the last, it will follow from it, that six parts of water, by being saturated with this gas, expanded so as to occupy very nearly the bulk of 11 parts; but in all the trials which were made upon it, the expansion was only nine parts. This would indicate a specific gravity of 1·477; yet upon actually trying water thus saturated, its specific gravity was only 1·203. Can this difference be owing to the gas that escapes during the acquisition of the specific gravity?

During the absorption of the gas, the water becomes hot. Ice also absorbs this gas, and is at the same time liquified. The quantity of this gas absorbed by water diminishes as the heat of the water increases, and at a boiling heat water will not absorb any of it. When water impregnated with it is heated, the gas is again expelled unaltered. Hence muriatic acid gas may be procured by heating the common muriatic acid of commerce. It was by this process, that Dr. Priestley first obtained it.

The acid thus obtained is colourless: it has a strong pungent smell similar to the gas, and when exposed to the air is constantly emitting visible white fumes. The muriatic acid of commerce is always of a pale yellow colour, owing to a small quantity of iron which it holds in solution.

As muriatic acid can only be used conveniently when dissolved in water, it is of much consequence to know how much pure acid is contained in a given quantity of liquid muriatic acid of any particular density. Now the specific gravity of the strongest muriatic acid that can easily be procured and preserved is 1·196: it would be needless, therefore, to examine the purity of any muriatic acid of superior density. Mr. Kirwan calculated that muriatic acid, of the density of 1·196, contains 0·2528 of pure acid.

Muriatic acid was long considered as

being capable of combining with oxygen, and forming with it compounds possessed of very different properties from the acid itself. But this theory has lately been abandoned by most of the leading chemists of the day, in consequence of the results of a number of experiments made upon this substance by Sir H. Davy, and subsequently by several other distinguished chemists both in this country and on the continent.

The result of these experiments, and the consequent change which they have produced on the whole science of chemistry, will be particularly noticed in treating of *Chlorine.**

It may, however be necessary to state here, that *muriatic acid* is now generally believed to be a *compound* of this substance and *hydrogen*.

ASTRONOMY.

OF THE HARVEST MOON.

It has long been known that the moon when full, about the time of harvest, rises for several nights nearly at the time of sun setting; but the cause of this remarkable phenomenon has not been so long known. This appearance was observed by the husbandman long before it was noticed by the Astronomer: and on account of its beneficial effects in affording a supply of light immediately after sun-set, at this important season of the year, it is called the *harvest moon*.

In order to conceive the reason of this phenomenon it must be recollected, that the moon is always opposite the sun when she is full, and of course in the opposite sign and degree of the zodiac. Now the sun is in the signs Virgo and Libra in August and September, or the time of harvest; and therefore the moon when full, in these months, is in the signs Pisces and Aries. But that part of the ecliptic in which Pisces and Aries is situated makes a much less angle with the horizon of places that have considerable northern latitude, than any other part of the ecliptic, and therefore a greater portion of it rises in any given time than an equal portion at any other part of it. Or, which is the same thing, any given portion of the ecliptic about Pisces and Aries rises in less space of time than an equal portion of it does at any other part. And as the moon's daily motion in her orbit is about 13°, this portion of it will require less time to rise about those signs, than an equal portion at any other part of the ecliptic; consequently, there will be less difference between the times of the moon's rising when in this part of her orbit than in any other.*

At a mean rate the moon rises 50 minutes later on any evening than she did the preceding evening; but when she is full about the beginning of September, or when she is in that part of her orbit which rises with the signs Pisces and Aries, she rises only about 16 or 17 minutes later than on the preceding evening; consequently, she will seem to rise for a few evenings at the same hour.

Although this is the case every time that the moon is in this part of her orbit; yet it is little attended to, except when she happens to be *full* at the time, which can only be in August or September.

In some years this phenomenon is much more perceptible than in others, even although the moon should be full on the same day, or in the same point of her orbit. This is owing to a variation in the angle which the moon's orbit makes with the horizon of the place where the phenomenon is observed. If the moon moved exactly in the ecliptic, this angle would always be the same at the same time of the year. But as the moon's orbit crosses the ecliptic and makes an angle with it of 5°. 9′, the angle formed by the moon's orbit and the horizon of any place is not exactly the same as that made by the ecliptic and the horizon. Some years it is greater and others less, even at the same time of the year, for it is subject to considerable variations, owing to the retrograde motion of the moon's *nodes*.†

If the ascending node should happen to be in the first degree of Aries, it is evident, that this part of the moon's orbit will rise with the least possible angle, and of course any given portion of it will require less time to rise than an equal portion in any other part of the orbit. The most favourable position of the nodes for producing the most beneficial harvest moons, is therefore, when the ascending node is in the first of *Aries*, and of course the descending in the first of *Libra*. When the nodes are in these points 13° of the moon's orbit, about the first of Aries, rises in the space of 16 minutes, in the latitude of London, and consequently, when the moon is in this part of her orbit, the time of her rising will differ only 16 minutes from the time

* This substance was formerly called oxymuriatic acid; but Sir H. Davy gave it this name in consequence of its green colour.

* It would tend very much to make this phenomenon understood if a terreetrial globe were at hand and rectified for the latitude of London, when reading this description.

† The *nodes*, or points where the moon's orbit crosses the ecliptic, move backward about 19° in a year, by which means they move round the ecliptic in 18 years 225 days.

she rose on the preceding evening. When the moon is in the opposite part of her orbit, or about the signs Virgo and Libra, which make the greatest angle with the horizon at rising, 13° of her orbit will require 1 h. 15′ to rise, although it were coincident with the ecliptic; and if the nodes be in the points just mentioned, the same portion of the orbit will require 1 h. 20′ to ascend above the horizon of the same place; and so much later will the moon rise every night for several nights when in this part of her orbit. As the moon is full in these signs in the months of March and April they may be called *vernal full moons*.

Those signs of the ecliptic which rise with the greatest angle set with the least; and those that rise with the least set with the greatest. Therefore, the vernal full moons differ as much in their times of *rising*, every night, as the autumnal, or harvest moons differ in the times of their *setting;* and they *set* with as little difference of time as the autumnal ones *rise*, supposing the full moons to happen in opposite points of the moon's orbit, and the nodes to remain in the same points of the ecliptic.

In southern latitudes, the harvest moons are just as regular as in the northern, because the seasons are contrary; and those parts of the moon's orbit about Virgo and Libra, where the *vernal* full moons happen in northern latitudes, (and the *harvest* ones in southern latitudes) rise at as small an angle at the same degree of *south* latitude, as those about Pisces and Aries in *north* latitude, where the autumnal full moons take place.

At places near the Equator, this phenomenon does not happen; for every point of the ecliptic, and nearly every point of the moon's orbit, makes the same angle with the *horizon*, both at rising and setting, and therefore equal portions of it will rise and set in equal times.

As the moon's nodes make a complete circuit of the ecliptic in 18 years 225 days, it is evident, that when the ascending node is in the first of Aries at any given time, the descending one must be in the same point about 9 years 112 days afterwards; consequently, there will be a regular interval of about 9 $\frac{1}{3}$ years between the *most* beneficial and *least* beneficial harvest moons.

APPARENT SIZE OF THE MOON.

It has been already remarked at page 202, that the apparent size of the moon is nearly equal to that of the sun; but the apparent size of the moon is not always the same, for she is often much nearer the earth at one time than another: hence, it is evident, her apparent magnitude must vary, and that it will be greatest when she is nearest the earth. (See page 203.)

But she appears larger when in the horizon than in the zenith even on the same evening; and yet it may easily be proved, that she is a semi-diameter of the earth, or about 4000 miles farther from the spectator when she is in the horizon than when she is in the zenith, and consequently ought to appear smaller, which will be found to be really the case if accurately measured.

This apparent increase of magnitude in the *horizontal* moon, must therefore be considered as an optical illusion; and may be explained upon the well known principle, that the eye in judging of distant objects is guided entirely by the previous knowledge which the mind has acquired of the intervening objects. Hence arise the erroneous estimates we make of the size of distant objects at sea, of objects below us when viewed from great heights, and of objects highly elevated when viewed from below. Now when the moon is near the zenith, she is seen precisely in this last situation, of course there is nothing near her, or that can be seen at the same time with which her size can be compared; but the *horizontal* moon may be compared with a number of objects whose magnitude is previously known.

That the moon appears under no greater an angle (or is not larger) in the horizon, than when she is on the meridian, may be proved by the following simple experiment.

Take a large sheet of paper and roll it up in the form of a tube of such width as just to include the whole of the moon when she rises; then tie a thread round it to keep it exactly of the same size, and when the moon comes to the meridian, where she will appear to the naked eye to be much less, look at her again through the same tube and she will fill it as completely as she did before.

When the moon is full and in the horizon, she appears of an *oval* form, with her longest diameter parallel to the horizon. This appearance is occasioned by the refraction of the atmosphere, which is always greatest at the horizon, consequently the lower limb or edge must be more refracted than the upper edge, and therefore these two edges will appear to be brought nearer each other, or the vertical diameter will appear to be shortened; and as the horizontal diameter is very little affected by the refraction, she must appear to have somewhat of an oval shape. The sun is affected in the same manner when in the horizon.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF JAMES FERGUSON.

James Ferguson, an eminent Experimental Philosopher, Mechanist, and Astronomer, was born in Banffshire, in Scotland, 1710, of very poor parents. At the very earliest age his extraordinary genius began to unfold itself. He first learned to read, by overhearing his father teach his elder brother: and he had made this acquisition before any one suspected it. He soon discovered a peculiar taste for Mechanics, which first arose on seeing his father use a long pole as a lever, to raising the roof of his cottage, which had sunk below the walls. He pursued this study a considerable length, while he was yet very young; and made a watch in wood work, from only once having seen one. As he had at first no instructor, nor any help from books, every thing he learned had all the merit of an original discovery; and such, with inexpressible joy, he believed it to be.

As soon as his age would permit, he went to service, in which he met with hardships, that rendered his constitution feeble through life. While he was servant to a farmer (whose goodness he acknowledges in the modest and humble account of himself, which he prefixed to his "Mechanical Exercises,") he contemplated and learned to know the stars, while he tended the sheep; and began the study of Astronomy, by laying down, from his own observations only, a celestial globe. His kind master, observing these marks of his ingenuity, procured him the countenance and assistance of some neighbouring gentlemen. By their help and instructions he went on gaining farther knowledge, having by their means been taught Arithmetic, with some Algebra and Practical Geomery. He had also got some notion of drawing, and being sent to Edinburgh, he there began to take portraits in miniature, at a small price, an employment by which he supported himself and family for several years, both in Scotland and England, while he was pursuing more serious studies. In London he first published some curious astronomical tables and calculations; and afterwards gave public Lectures in Experimental Philosophy, both in London and most of the country towns in England, with the highest marks of general approbation. He was elected a fellow of the Royal Society, and was excused the payment of the admission fee, and the usual annual contributions. He enjoyed from the king a pension of fifty pounds a year, besides other occasional presents, which he privately accepted and received from different quarters, till the time of his death; by which, and the fruits of his own labours, he left behind him a sum to the amount of about six thousand pounds, although all his friends had always entertained an idea of his great poverty. He died in 1776, at sixty-six years of age, though he had the appearance of many more years.

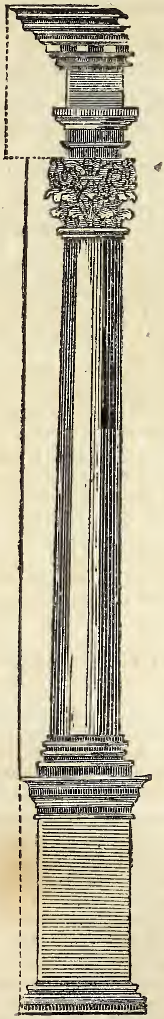
Mr. Ferguson must be allowed to have been a very uncommon genius, especially in mechanical contrivances and executions, for he executed many machines himself in a very neat manner. He had also a good taste in Astronomy, as well as in Natural and Experimental Philosophy, and was possessed of a happy manner of explaining himself in an easy, clear, and familiar way. His general mathematical knowledge, however, was very limited. Of algebra he understood but little more than the notation; and he has often told the late Dr. Hutton, that he could never demonstrate one proposition in Euclid's Elements; his constant method being to satisfy himself as to the truth of any problem, with a measurement by scale and compasses. He was a man of a very clear judgment in any thing that he professed, and of unwearied application to study; benevolent, meek, and innocent in his manners as a child: humble, courteous, and communicative: instead of pedantry, philosophy seemed to produce in him only diffidence and urbanity.

The following is a list of Mr. Ferguson's works:—

1. "Astronomical Tables and Precepts, for calculating the true Times of New and Full Moons, &c." 1763; 2. "Tables and Tracts, relative to several Arts and Sciences;" 3. "An easy Introduction to Astronomy, for young Gentlemen and Ladies;" 4. "Astronomy explained upon Sir Isaac Newton's Principles;" 5. "Lectures on select Subjects in Mechanics, Hydrostatics, Pneumatics, and Optics;" 6. "Select Mechanical Exercises, with a short Account of the Life of the Author by himself," a narrative highly interesting and amusing: 7. The Art of Drawing in Perspective made Easy;" 8. "An Introduction to Electricity," 1775; "Three Letters to the Rev. Mr. John Kennedy." He communicated also several papers to the Royal Society, which were printed in their Transactions. In 1805 a very valuable edition of his Lectures was published in Edinburgh by Dr. Brewster, in 2 vols. 8vo. with notes and an appendix.

ARCHITECTURE.

COMPOSITE ORDER.



The Composite Order, is the last of the five orders of columns; so called, because its capital is *composed* out of those of the other orders.

It borrows a quarter-round from the Tuscan and Doric; a double row of leaves, from the Corinthian; and Volutes from the Ionic: its cornice has simple modillions, or dentils.

The *composite* is also called the *Roman* and *Italian* order; as having been invented by the Romans; conformably to the rest, which are denominated from the people among whom they had their rise.

Most authors rank this after the Corinthian; either as being the richest, or as the last that was invented: Scamozzi alone places it between the Ionic and Corinthian; out of a view to its delicacy and richness, which he esteems inferior to that of the Corinthian; and therefore makes no scruple to use it under the Corinthian: wherein he is followed by M. le Clerc. The proportions of this order are not fixed by Vitruvius; he only marks its general character, by observing, that its capital is composed of several parts taken from the Doric, Ionic, and Corinthian: he does not seem to regard it as a particular order; nor does he vary it at all from the Corinthian, except in its capital. In effect, it was Serlio who first added the *composite* order to the four of Vitruvius, forming it from the remains of the temple of Bacchus, the arches of Titus, Septimus, and the Goldsmiths at Rome: till then, this order was esteemed a species of the Corinthian, only differing in its capital.

The order being thus left undetermined by the ancients, the moderns have a kind of right to differ about its proportions, &c. Scamozzi, and after him M. le Clerc, make its column 19 modules and a half; which is less by half a module than the Corinthian. Vignola makes it 20; which is the same with that of his Corinthian: but Serlio, who first formed it into an order, by giving it a proper entablature and base, and after him M. Perrault, raise it still higher than the Corinthian.

This last does not think different ornaments and characters sufficient to constitute a different order, unless it have a different height too: agreeably, therefore, to his rule of augmenting the heights of the several columns by a series of two modules in each; he makes the *composite* 20 modules, and the Corinthian 18; which, it seems is a medium between the porch of Titus and the temple of Bacchus.

M. Perrault, in his Vitruvius, distinguishes between composite and composed order. The latter, he says, denotes any composition whose parts and ornaments are extraordinary, and unusual; but have, withal, somewhat of beauty; both on account of their novelty, and in respect of the manner, or genius of the architect: so that a *composed* order is an arbitrary, humorous composition, whether regular or irregular.

The same author adds, that the Corinthian order is the first composite order, as being composed of the Doric and Ionic; which is the observation of Vitruvius himself.

CELESTIAL ATLAS BY ALEXANDER JAMEISON, A. M.

It is a species of anomaly in the literature of this country to see a work make its appearance on certain sciences, which are not only useful in themselves, but are the foundation of almost all accurate science. Among these it is only necessary to mention Mathematics and Astronomy. For though we have Systems, Courses, Preceptors and Catechisms in abundance, on those sciences as well as on music, dancing and boxing, yet they contain nothing that has not been before the public a thousand times in as many different shapes. Every teacher of a petty boarding school has either got his system of Arithmetic, Mathematics, or Astronomy, although he can neither demonstrate a proposition in Euclid, nor tell the time of new moon without his Moor's Almanack.

But with all these works on the sciences just mentioned, we have nothing original, nothing that is even *new in appearance* to those who have made a little progress in the sciences of mathematics or astronomy.

We may venture to assert, that there has scarcely been a single work published in this country within the last forty years, which has added any thing to our stock of mathematical or astronomical knowledge. Discoveries and improvements have been made in those sciences within this period, and we are now in *possession* of some of them; but this is by means of translations from works which have first appeared in other countries, and not by having been originally published here. The fact is, that instead of mathematical and astronomical knowledge having increased in this country, during the above period it has diminished. And instead of the high rank which we once held in this respect among our neighbours, we are now unquestionably inferior to them. What has caused this change we shall not at present enquire into; but the effect of it has been such as to go far in not only preventing original publications from making their appearance among us on these sciences, but even of translations. For where is the individual who will venture to publish a work, however valuable that work may be to the public, when he is almost certain that he must lose by its publication.

There are certainly exceptions to this, for some persons are to be found who publish valuable works, when there is scarcely a possibility of their sale defraying the necessary expenses attendant upon bringing them before the public.

An instance of this we believe we have before us in the case of the "Celestial Atlas," lately published by Mr. Jamieson. This is a work completely new in its kind, at least we have no work of the kind in this country, to which *the public have access.*

It consists of thirty beautifully engraved maps of the heavens, on which are delineated the figures of the most conspicuous constellations in the Zodiac, and the Northern and Southern hemispheres, with the greater number of the stars that are visible in each. The stars appear to be very accurately laid down, and consequently must render the maps very useful to those who wish to become acquainted with the relative situations of the stars in the heavens.

Mr. Jamieson has also explained the manner of using these maps, and subjoined a number of problems with appropriate exercises to each map, by which means his atlas may supply the place of a Celestial Globe. But what is perhaps of more importance to the scientific astronomer, is the extensive and accurate Catalogues of the Stars in each constellation, with their Right Ascension and Declaration for the beginning of the year 1820.

To render this work still more valuable, Mr. J. had added a number of astronomical Tables, and given very clear definitions of the principal circles of the Sphere. On the whole we consider this Atlas as a very great addition to the works we already possess on the sublime and almost neglected science of astronomy; and we are convinced, that not only the student, but the proficients in this branch of physical knowledge will derive advantage from the perusal of the Celestial Atlas.

We are happy to see that a work which has cost so much expense and research, has met with the patronage of his present Majesty, to whom it is dedicated by permission.

ANALOGY BETWEEN THE PHENOMENA OF GALVANISM AND THAT OF FERMENTATION.

M. Schweigger, a German chemist, has remarked that there is a very great analogy between the phenomena produced by the galvanic pile, and those which accompany fermentation.

1. Piles, as well as all fermentable mixtures, only exhibit their effects by the reciprocal action of three different bodies.

2. The products of galvanic action are two in number; namely, oxygen and hydrogen. The same number are produced by fermentation; viz. alcohol and carbonic acid.

3. What is little known, and what M. Schweigger believes, he can establish by experiment is, that the presence of bodies negatively electrified, favour the decomposition of water, whilst, from the nice experiments of M. Dobereiner, bodies positively electrified aid its formation; and

the same bodies negatively electrified, augment the effects of fermentation.

Mr. Schweigger thinks that the same results may yet be obtained with fermentable mixtures as with electric batteries.

To these considerations he adds some simple experiments made upon the production of light by crystallization, and advises philosophers not to neglect the study of these phenomena.

TO IMITATE LEAF-GILDING ON LEATHER.

Take some calf-skins which have been softened in water, and beat on a stone to their greatest extent whilst wet; rub the grain side of the leather with a piece of size, whilst in a state of jelly; and before this size dries, lay on a number of silver leaves. When covered with the silver leaf, the skins are to be dried till they are in a proper state for burnishing, which is performed by a piece of large flint fixed in a wooden handle; the appearance of gold is then given to the silvered surface by covering it with a yellow varnish, or lacker, which is composed of four parts of white resin, the same quantity of common resin, two parts of gum sandarac, and two parts of aloes. These ingredients are to be melted together in an earthen vessel, and after being well mixed by stirring, twenty parts of linseed oil is to be poured in, and when the composition is sufficiently boiled to make a perfect union, and to have the consistence of a syrup, half an ounce of red-lead is to be added, and the liquid passed through a flannel bag. To apply this varnish, the skins must be spread out upon a board, fastened down by nails, and exposed to the rays of the sun, and when thus warmed, the white of an egg is to be spread over the silver. After it is dry the varnish is laid on, which will dry in a few hours, and is very durable.

TO ASCERTAIN THE QUANTITY OF ALCOHOL CONTAINED IN ALE OR PORTER.

Take any measured quantity of ale, or porter, and put it into a glass retort, connected with a close receiver; distil with a gentle heat as long as any spirit passes over into the receiver, which may be known by heating a small quantity of the fluid in a tea-spoon over a candle, from time to time. If the vapour catches fire, the distillation must be continued till the vapour ceases to burn when brought in contact with flame. The distilled liquid is the spirit of the beer combined with water; put this spirit into a tube divided into one hundred equal parts, and add pure dry subcarbonate of potash till it fall undissolved to the bottom of the tube; the spirit will thus be separated from the water, and float on the top; hence the quantity of real spirit, or alcohol, per cent. may be easily determined.

CONSTRUCTION OF BALLOONS.

The shape of the balloon is one of the first objects of consideration. As a sphere admits the greatest capacity under the least surface, the spherical figure, or that which approaches nearest to it, has been generally preferred. However, since bodies of this form oppose a great surface to the air, and, consequently, a greater obstruction to the action of the oar or wings, than those of some other form, it has been proposed to construct balloons of a conical or oblong figure, and to make them proceed, with their narrow end forward. Some have suggested the shape of a fish; others, that of a bird; but either the globular, or the egg-like shape, is, all things considered, certainly the best which can be adopted.

The bag or cover, of an inflammable-air balloon, is best made of the silk stuff called lustring, varnished over. But for a Montgolfier, or heated-air balloon, on account of its great size, linen cloth has been used, lined within or without with paper, and varnished. Small balloons are made either of varnished paper, or simply of paper unvarnished, or of gold-beaters' skin, and such like light substances. The best way to make up the whole coating of the balloon, is by different pieces, or slips, joined lengthways from end to end, like the pieces composing the surface of a geographical globe, and contained between one meridian and another; or like the slices into which a melon is usually cut, and supposed to be spread out flat.

After providing the necessary quantity of the stuff, and each piece having been properly prepared with drying oil, let the corresponding edges be sewed together in such a manner as to leave about half, or three quarters, of an inch of one piece, beyond the edge of the other; in order that this may, in a subsequent row of stitches, be turned over the latter, and both again sewed down together; by so doing, a considerable degree of strength is given to the whole bag at the seams, and the hazard of the gas escaping, is doubly prevented. Having gone in this manner through all the seams, the following method of M. Blanchard is admirably calculated to render them yet more perfectly air tight. The seam being doubly stitched, as above, lay beneath it a piece of brown paper, and also another piece over it on the outside; upon this latter, pass several times a common fire-iron, heated just sufficiently to soften the drying oil in the seam; this done, every interstice will be now closed, and the seams rendered completely air tight. The neck of the balloon being left a foot in diameter, and three in length, and all the seams finished, the bag will be ready to receive the varnish, a single coating of which on the outside is found preferable to the former method of giving an internal as well as an external coat.

The car, or boat, is best made of wicker-work, covered with leather, and painted; and the proper method of suspending it, is by ropes proceeding from the net which goes over the balloon. The net should be formed to the shape of the balloon, and fall down to the middle of it, with various cords proceeding from it to the circumference of a circle about two feet below the balloon; and from that circle other ropes should go to the edge of the boat. This circle may be made of wood, or of several pieces of slender cane bound together. The meshes of the net may be small at top, against which part of the balloon, the inflammable air exerts the greatest force; and increase in size as they recede from the top.

If a parachute is required, it should be constructed so, as, when distended, to form but a small segment of a sphere, and not a complete hemisphere; as the weight of this machine is otherwise considerably increased, without gaining much in the opposing surface. The parachute of M. Garnerin is perticularly defective in the too great extension of its diameter; viz. by an unnecessary addition to its weight of a lining of paper, both withinside, and without; and in the too near approximation of the basket to the body of the parachute; but especially, in the want of a perpendicular cord passing from the car to the centre of the concave of the umbrella; by the absence of which, the velocity of the descent is certain to be very rapid before the machine becomes at all distended. Whereas, if a cord were thus disposed, the centre of the parachute would be the portion first drawn downwards by the appended weight, and the machine would be almost immediately at its full extension. Having found, by experiment, the diameter, required for insuring safety, the further the basket, or car, is from the umbrella, the less fear shall we have of an inversion of the whole from violent oscillations; yet, the longer the space between the car and the head of the machine, the longer will be the space run through, in each vibration, when once begun; still, by so much the more, will they be steadier. This ought to be attended to, as, when by the violence of the oscillations, the car became (in Garnerin's experiment) on a line with the horizontal axis of the machine; the gravitating power of the weight in the car, on the umbrella, being at that crisis reduced to nothing, the slightest cause might have carried the body of the machine in a lateral direction, reversing the concavity of the umbrella; and M. Garnerin, might, perhaps, have fallen upon the (now) convex, yet internal portion of the bag: consequently the whole would have descended confusedly together.

MANUFACTURE OF MOSAIC AT ROME.

It is well known that Mosaic-work consists of variously shaped pieces of coloured glass enamel; and that when these pieces are cemented together, they form those regular and other beautiful figures which constitute tessellated pavements. These pavements, the work of the ancient Romans, have frequently been dug up in England and other countries. The principal manufactory of Mosaic pictures in the present day, is at Rome, and belongs to his Holiness the Pope.

The enamel, consisting of glass mixed with metallic colouring matter, is heated for eight days in a glass-house, each colour in a separate pot. The melted enamel is taken out with an iron spoon, and poured on polished marble placed horizontally; and another flat marble slab is laid upon the surface, so that the enamel cools into the form of a round cake, of the thickness of $\frac{3}{10}$ of an inch.

In order to divide the cake into smaller pieces, it is placed on a sharp steel anvil, called Tagliulo, which has the edge uppermost; and a stroke of an edged hammer is given on the upper surface of the cake, which is thus divided into long parallelopipeds, or prisms, whose bases are $\frac{3}{10}$ of an inch square. These parallelopipeds are again divided across their length by the tagliulo and hammer into pieces of the length of $\frac{6}{10}$ of an inch, to be used in the Mosaic pictures. Sometimes the cakes are made thicker, and the pieces larger.

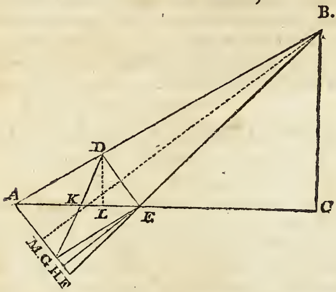
For smaller pictures, the enamel, whilst fused, is drawn into long parallelopipeds, or quadrangular sticks; and these are divided across by the tagliulo and hammer, or by a file; sometimes, also, these pieces are divided by a saw without teeth, consisting of a copper blade and emery; and the pieces are sometimes polished on a horizontal wheel of lead with emery.

Gilded Mosaic is formed by applying the gold-leaf on the hot surface of a brown enamel, immediately after the enamel is taken from the furnace; the whole is put into the furnace again for a short time, and when it is taken out the gold is firmly fixed on the surface. In the gilded enamel, used, in Mosaic, at Rome, there is *a thin coat of transparent glass* over the gold.

SOLUTIONS OF QUESTIONS.

QUEST. 31, *answered by a* MECHANIC, *of Bury (the proposer).*

DEMONS. Produce B E to F,



making F B = B A. Draw A F, which will evidently be parallel to D E. Let fall the perpendicular B M, which will bisect A F. Draw E G parallel to A D. Let fall the perpendiculars E H and E L, and draw the Diameter D G. Now D G is a parallelogram and its opposite sides and angles are equal (Euc. 34-1); hence A G and G E are known because D E and A D are given, and by subtraction we have E F = A D = E G ∴ E F is known. But A E is given, now $AE^2 = EG^2 + AG^2 + 2\overline{AG \times GH}$ (Euc. 12-2). Now AE^2, EG^2, and AG^2 are known; therefore 2 $(AG \times GH)$ and consequently $\overline{AG \times GH}$ are known; and since A G is known G H is so likewise. But G H = H F: therefore H F is known also, whence by addition A F becomes known, and A M = M F is known by division. Then by similar triangles H F : F E : : M F : F B = A B which is therefore known. Now, by Bonnycastle's Geometry, Book 2. Prop. 21. A E and D G bisect each other in K and $AE^2 + DG^2 = AD^2 + DE^2 + EG^2 + GA^2$, but the four last, and also the first, viz. AE^2 are known; therefore DG^2 is known by subtraction and by extracting root D G is known. But $DK = \frac{GD}{2}$, hence D K is known: and as we found G H so we find K L: therefore by (Euc. 47-1) D L is known, then by similar triangles A D : D L : : A B : B C. Q. E. D.

QUEST. 32, *answered by* Mr. J. HOLROYD, *Of Oldham.*

Let x represent the height of the house, then by Euc. 1 and 47 $\sqrt{x^2 + (12)^2}$ = the length of the ladder in the 1st position; and $\sqrt{(x-4)^2 + (20)^2}$, the same in the 2d position; therefore $\sqrt{x^2 + (12)^2} = \sqrt{(x-4)^2 + (20)^2}$, or $x^2 + 144 = x^2 - 8x + 416$, consequently $x = 34$ feet, the height of the house required; and the length of the ladder is therefore 36·055 feet.

This question was also correctly solved by the following Correspondents: Messrs. A. PEACOCK, *St. Georges, East;* JOHN BARR, *Somer's Town;* GEORGR FUTVOYE, *High-street, Mary-la-bonne;* and J. WHITECOMBE, *Cornhill.*

QUEST. 33, *answered by* Mr. JOHN BARR, *Somer's Town.*

The nature of the question is to determine the difference between the area of the circumscribing square and the inscribed circle, therefore put x for the difference. a = ·925 the diameter of the circle; then a^2 = the area of the square; and let r and s represent the numbers 113 and 355 respectively.

When $r : s :: a : \frac{sa}{r}$ the circumference of the circle;

and $\frac{a}{4} \times \frac{sa}{r} = \frac{sa^2}{4r}$ the area of the circle;

whence $x = a^2 - \frac{sa^2}{4r}$ = ·1837 parts of an inch, the area of the space required.

This question was also answered by all the gentlemen who solved the 32d question, and by S. A. HART, STUDENT, ROYAL ACADEMY; SUBPRECEPTOR; and the Proposer.

QUESTIONS FOR SOLUTION.

QUEST. 37, *proposed by* FR—D+F—LK—WO—TH.

Required a theorem for finding the area of a circle, having only the cord of half the arch, and the versed sine of it given?

QUEST. 38, *proposed by* Mr. R. GRAHAM, *Liverpool.*

There is a regular tetrahedron of pebble on the side of the Queen's Dock, Liverpool, whose whole surface in feet is equal to the sum of its linear edges; it is required to determine the least quantity, and the value of standard gold added to the surfaces that will make it a globe, and also the diameter of a globe of cork, which, when fixed to the foresaid globe, and put into the Dock at full tide, the cork globe may be just covered with water?

QUEST. 39, *proposed by* G. G. C.

Suppose a pillar 150 feet high, on which is placed a statue 10 feet high; required a point on a level with the base of the pillar, such that the angle subtended by the statue may be the greatest possible, and also to determine what that angle is?

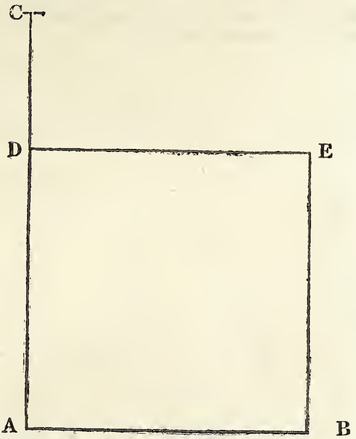
GEOMETRY.

PROPOSITION XLVI.

Problem.—*To describe a square upon a given straight line.*

Let A B be the given straight line; it is required to describe a square upon A B.

From the point A draw A C at right angles to A B; and make A D equal to A B, and through the point D draw D E parallel to A B, and through B draw B E parallel to A D; therefore A D E B is a parallelogram:



Whence A B is equal to D E, and A D to B E: but B A is equal to A D; therefore the four straight lines B A, A D, D E, E B, are equal to one another, and the parallelogram A D E B is equilateral: it is likewise rectangular; for the straight line A D meeting the parallels A B, D E, makes the angles B A D, A D E equal to two right angles; but B A D is a right angle; therefore also A D E is a right angle; now the opposite angles of parallelograms are equal; therefore each of the opposite angles A B E, B E D is a right angle; wherefore the figure A D E B is rectangular, and it has been demonstrated that it is equilateral; it is therefore a square, and it is described upon the given straiget line A B. Which was to be done.

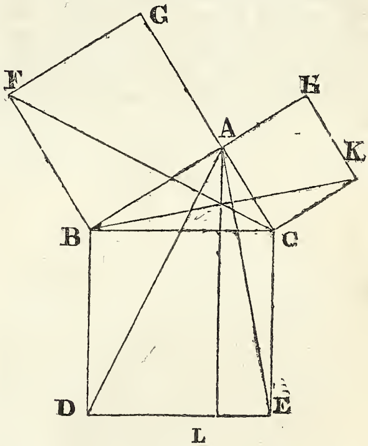
Cor. Hence every parallelogram that has one right angle has all its angles right angles.

PROPOSITION XLVII.

Theorem.—*In any right angled triangle, the square which is described upon the side subtending the right angle, is equal to the squares described upon the sides which contain the right angle.**

Let A B C be a right angled triangle, having the right angle B A C; the square described upon the side B C is equal to the squares described upon B A, A C.

On B C describe the square B D E C, and on B A, A C the squares G B, H C; and through A draw A L parallel to B D or C E, and join A D, F C; then, because each of the angles B A C, B A G is a right



angle, the two straight lines A C, A G upon the opposite sides of A B, make with it at the point A the adjacent angles equal to two right angles; therefore C A is in the same straight line with A G; for the same reason, A B and A H are in the same straight line. Now because the angle D B C is equal to the angle F B A, each of them being a right angle, adding to each the angle A B C, the whole angle D B A will be equal to the whole F B C; and because the two sides A B, B D, are equal to the two F B, B C, each to each, and the angle D B A equal to the angle F B C, therefore the base A D is equal to the base F C, and the triangle A B D to the triangle F B C: but the parallelogram B L is double of the triangle A B D, because they are upon the same base B D, and between the same parallels, B D, A L; and the square G B is double of the triangle B F C, because these also are upon the same base F B, and between the same parallels F B, G C. Now the doubles of equals are equal to one another; therefore the parallelogram B L is equal to the square G B: And, in the same manner, by joining A E, B K, it is demonstrated that the parallelogram C L is equal to the square H C. Therefore, the whole square B D E C is equal to the two squares G B, H C; and the square B D E C is described upon the straight line B C, and the squares G B, H C upon B A, A C; wherefore the square upon the side B C is equal to the square

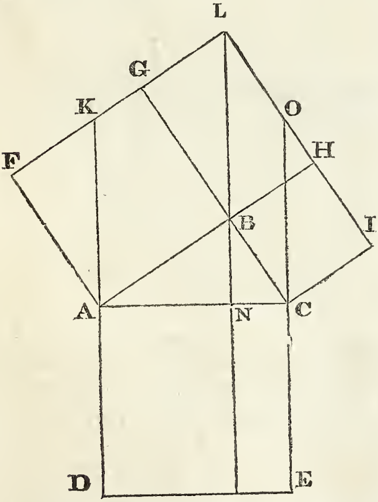
* This proposition is often called the Pythagorean Theorem, from Pythagoras, who is said to have been the discoverer of the remarkable property here proved by it; and it is also said, that he considered it of so great importance, that he sacrificed a hecatomb or 100 oxen, on making the discovery of its truth.

upon the sides B A, A C. Therefore, in any right angled triangle, &c. Q. E. D.

Observation.—This famous proposition has been proved in a variety of ways by several celebrated mathematicians. The following, however, appears to be one of the most simple:

Let the triangle A B C be right-angled at B.

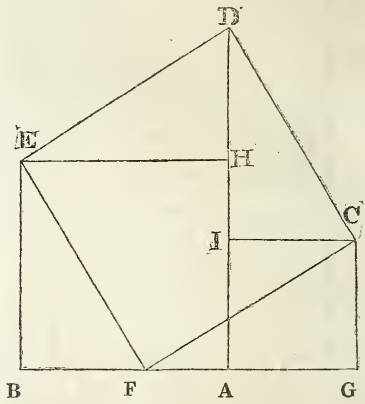
Upon A C describe the square A C E D, and upon A B and B C describe the squares A B G F, and B C I H, and produce D A to K and E C to H; produce I H and F G till they meet in L, and through B draw L B M parallel to D A or E C.



Because the angle C A K, adjacent to C A D, is a right angle, it is equal to BAF; from each of these take away the angle B A K, and there remains the angle B A C equal to F A K. But the angle A B C is equal to A F K, both being right angles. Wherefore the triangles A B C and A F K, having thus two angles in the one respectively equal to those of the other, and the interjacent side A F equal to A B, are equal (I. 26), and consequently the side A K is equal to A C. Hence the parallelogram A M is equal to the parallelogram or rhomboid A B L K, since they stand upon equal bases A D and A K, and between the same parallels D K and M L. But A B L K is equal to the square B F, for it stands on the same base A B, and between the same parallels F L and A H. Wherefore the parallelogram A M is equal to the square on A B. And in the same manner it may be proved, that the parallelogram C M is equal to the square described on B C. Consequently the whole square A D E C, on the side A C, contains the same space as both the squares described on the two sides A B, and B C.*

As it may gratify the young student in Geometry, to be able to prove this proposition experimentally, we shall show that the two squares on the sides containing the right angle may be cut, so that the parts will just make up the square on the hypothenuse.

Let A B C be a right angled triangle right angled at B. Upon A C describe the square A E D C; from the points D E, draw D F, and E G, perpendicular to B A produced; and through E and C draw E H, and C I, parallel to A B.



Now, in the triangles A B C, D I C, the angles B and I, being right angles, are equal; and because each of the angles B C I, A C D, is a right angle, take away the angle A C I, which is common to both, and the remaining angles A C B, I C D, will be equal; hence the triangles are equiangular; and since the sides A C, C D, opposite the right angles, are equal, the triangles are, therefore, equal, and the remaining sides of the one, equal to those of the other, each to each, to which the equal angles are opposite; that is, D I is equal to A B, and C I to B C. Now, since the figure B C I F has all its sides equal, and all its angles right angles, it is, therefore, a square; and it is the square of B C. In like manner it may be shewn, that the triangles E H D, E G A, are each similar and equal to A B C; and hence also, the figure E G F H, is the square of A B. Now, the portions of the two squares, contained within the square A C D E, together with the triangles E H D, D I C, make up the whole of that square. But the triangles

* The side opposite to the right angle, is called the *Hypothenuse.*

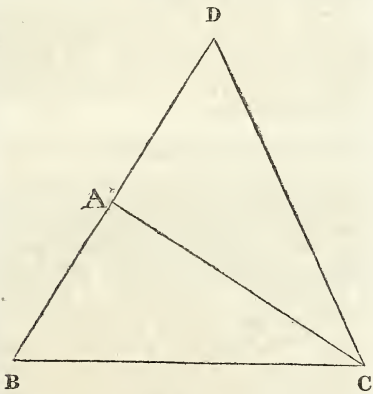
EHD, DIC, are equal to the triangles EGA, ABC: hence the square of AC is equal to the sum of the squares AB and BC.*

PROPOSITION XLVIII.

THEOREM.—*If the square described upon one of the sides of a triangle, be equal to the squares described upon the other two sides of it; the angle contained by these two sides is a right angle.*

If the square described upon BC, one of the sides of the triangle ABC, be equal to the squares upon the other sides BA, AC, the angle BAC is a right angle.

From the point A draw AD at right angles to AC, and make AD equal to BA, and join DC. Then, because DA is equal to AB, the square of DA is equal to the square of AB: To each of these add the square of AC; therefore the squares of DA, AC, are equal to the squares of BA, AC. But the square of DC is equal to the squares of DA, AC, because DAC is a right angle; and the square of BC, by hypothesis, is equal to the squares of BA, AC; therefore, the square of DC is equal to the square of BC: and therefore also the side DC is equal to the side BC. And because the side DA is equal to AB, and AC common to the two triangles DAC and BAC, and the base DC being likewise equal to the base BC, the angle DAC is equal to the angle BAC: but DAC is a right angle; therefore also BAC is a right angle. Q. E. D.



* We leave it as an exercise for the student, to put the parts together, so as to form the large square out of the parts into which the two small ones are here divided, by the lines drawn in the figure.

Having now arrived at the conclusion of the *first book* of the Elements, we may remark that many of these proposition are only useful in proving others.

The 16th proposition, for example, is evidently implied in the 32d., and is therefore useless after the 32d is demonstrated. But the propositions are all arranged in the order in which they are wanted for the demonstration of those that follow, without any regard to their subjects. By this means nothing is ever assumed in any proposition that has not been previously proved in some preceding proposition. Hence arises the advantage of following the arrangement which Euclid has adopted, rather than making partial selections of particular propositions.

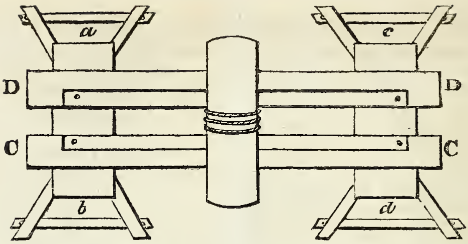
MECHANICS.

ON THE FRICTION AND RIGIDITY OF ROPES.

The first experiments that appear to have been made on the rigidity of ropes, were those of Amontons, who contrived an ingenious appartus for this purpose. He has published, in the Memoirs of the Academy of Sciences for 1699, a table of the forces required to bend ropes, founded on the supposition that the difficulty of bending a rope of the same thickness, and loaded with the same weight, " decreases when the diameter of the roller or pulley increases, but not so much as that diameter increases.

Another series of experiments was afterwards made by Desaguliers, who published a table, " shewing what forces were required to bend ropes of different diameters, stretched by different weights round rollers of different sizes." The general result of these experiments was, *that the difficulty of bending a rope round a roller*, is, *cæteris paribus*, inversely as the diameter of the roller.

The experiments on the rigidity and friction of ropes made by Coulomb, were performed, both with the apparatus used by Amontons, and another of his own, which is represented by the following figure:



It consists of two tressels 6 feet high, on which are laid two pieces of square wood, *a b*, *c d*. On these two pieces are fixed two rulers of oak, DD CC, well planed and polished with fish-skins. With two cylinders of *lignum vitæ*, one 6 inches in diameter, and the other 2 inches; and with several cylinders of elm, from 2 to 12 inches in diameter, the apparatus was ready for the experiments being made.

In order to ascertain the friction of the rollers, they were laid on planks, as shown in the above figure.

A weight of 50 lbs. was suspended on each side of the roller, with very fine and flexible pack-thread; and the weights could be increased in any degree, by laying additional weights of 50 lbs. by different threads, so as to give any required pressure to the rollers. By adding a counterweight on each side of the roller alternately, till they received a motion barely sensible, Coulomb ascertained the friction of the rollers.

The following are the general results of Coulomb's experiments:

1. The rigidity of ropes increases the more that the fibres of which they are composed are twisted.

2. The rigidity of ropes increases in the duplicate ratio (or as the squares) of their diameters. According to Amontons and Desaguliers, the rigidity increases in the simple ratio of the diameters of the ropes; but this probably arose from the flexibility of the ropes which they employed.

3. The rigidity of the ropes is in the simple and direct ratio of their tension.

4. The rigidity of the ropes is in the inverse ratio of the diameters of the cylinders round which they are coiled. This result was obtained also by Desaguliers.

5. In general, the rigidity of the ropes is directly as their tensions and the squares of their diameters, and inversely as the diameters of the cylinders round which they are coiled.

6. The rigidity of ropes increases so little with the velocity of the machine, that it need not be taken into the account when computing the effects of machines.

7. The rigidity of small ropes is diminished when penetrated with moisture; but when the ropes are thick, their rigidity is increased.

8. The rigidity of ropes is increased, and their *strength* diminished, when they are covered with pitch; but when ropes of this kind are alternately immersed in the sea and exposed to the air, they last longer than when they are not pitched. This increase of rigidity, however, is not so perceptible in small ropes as in those which are pretty thick.

9. The rigidity of ropes covered with pitch is a sixth part greater during frost than in the middle of summer; but this increase of rigidity does not follow the ratio of their tensions.

ON THE FRICTION AND FORM OF PIVOTS.

The *needles of compasses* are generally suspended upon a pivot, by means of caps of agate, or other hard substances. The cap has a conical form, terminated above with a small concave summit, whose radius of curvature is very small. The pivots themselves are generally of tempered steel, but frequently reduced to the state of a spring. The point of the pivot which supports the cap is a small curve surface, whose radius of curvature is smaller than that of the summit of the cap. Coulomb generally found, that even when every care was taken by the artist, the curvature of the summit of the cap was very irregular, and that the friction of an agate cap, turning upon the point of a pivot, was often five or six times greater than the momentum of friction of a highly polished agate plane turning on the same pivot.

Coulomb, in his experiments on pivots, supported the body by a highly polished plane in place of a cap, and having given it a rotatory motion, he noted, by means of a seconds watch, the time employed in making the *four* or *five* first turns, from a mean of which he obtained the primitive velocity; and he next counted the number of turns which it made before it stopped. The revolving body is obviously brought to rest by the friction of the point of the pivot, and also by the resistance of the air; but in order to get rid of this last resistance, Coulomb gave the body the form of a glass receiver, and found, that when the velocity was not great, and when the receiver weighed 5 or 6 gros (a gros is the ght h of an ounce), the resistance of the air bore no sensible ratio to that of the friction. In order to render the results more certain, he made several of the experiments in vacuo.

The following are some of the results which Coulomb obtained:

1. The friction of pivots is independent of the velocities, and bears some proportion to the pressure.

2. The friction of garnet is less than that of agate, and that of agate less than that of glass; but the friction of different parts of a plane of polished glass is less irregular.

3. The angles of the points of pivots has an influence on the friction. When the body weighs five or six gros, the best angle is from 30 to 45 degrees. When the body weighs less, the angle of the pivot may be progressively diminished without the friction experiencing any sensible increase. We may even without much inconvenience, and when the steel is good, reduce it to 10 and 12 degrees, provided the weight of the body does not exceed a hundred grains.

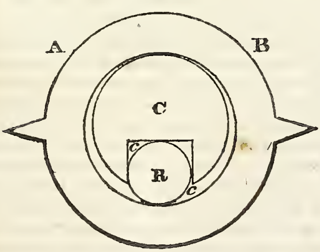
4. With a pivot of the best steel, well tempered, and brought to the first degree of steel temper, and having an angle of 45 degrees, the momentum of friction varies as the $\frac{4}{3}$d power of the pressure.* When the pressure was very considerable, and the pivot shaped to any angle, the friction varied nearly as the pressure.

5. All the caps which Coulomb procured from the best workmen, appeared to be very irregular in their concavity. The momentum of their friction, under pressures of even more than five or six grains, is always quadruple of that of a well-polished plane of the same substance; and in order to support these caps, it is necessary that the points of the pivots be shaped to an angle less than that which is necessary to support planes.

METHODS OF DIMINISHING FRICTION IN MACHINERY.

The experiments which have been detailed above, will furnish the practical mechanic with various rules respecting the nature and form of the materials which should form the supports and communicating parts of machines, respecting the nature of the unguents which should be applied to them, and the mode of their application.

Fig. 1.

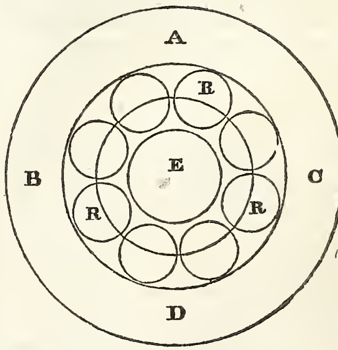


The most efficacious contrivances for diminishing friction, are *friction wheels*,† by means of which, that species of friction which arises from one body being dragged over another, is changed into that which arises from one body rolling upon another. The application of friction-wheels is shown in the following figures:

Fig. 1st represents M. Gottlieb's anti-attrition axle-tree, and which consists of a steel roller R, about five inches long, turning in a groove cut in the lower part of the axle-tree C, which works on the nave A B.

Fig. 2d, shows the method of applying friction-rollers used by Mr. Gamett. A space between the axle E, and the nave of the wheel A B D C, is filled with friction-rollers, R, R, R, &c. whose axes are inserted in circles of brass, which are rivetted together by means of bolts which pass between the rollers, in order to keep them separate and parallel. When the moving force is not exerted in a perpendicular direction, but obliquely, as in undershot-wheels, the gudgeon will press with greater force on one part of the socket than on any other part. This point will evidently be on the side of the bush opposite to that where the power is applied; and its distance from the lowest point of the socket, which is supposed circular and

Fig. 2.



* That is the pressure or weight multiplied four times into itself and the cube root extracted.

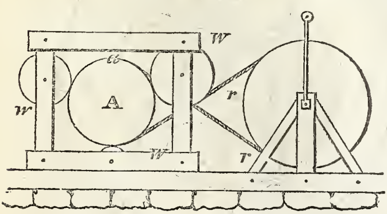
† When each end of the axis of a wheel is made to turn, not in a groove, but on the circumference of two wheels, every one moveable on its own axis, these last are called Friction Wheels, as serving very much to lessen the effects of friction.

concentric with the gudgeon, and may be determined by calculation.

Friction-wheels seem to have been first recommended by Casatus. They were afterwards mentioned by Sturmius and Wolfius, but were not in actual use till Sully applied them to clocks in 1716, and Mondran to cranes in 1725. They remained, however, almost unnoticed till the celebrated Euler explained their nature and advantages in his memoirs on *Friction.* Another method of diminishing friction, is to apply the impelling power (when it can be done) in such a way, as to act either in opposition or obliquely, to the force of gravity.

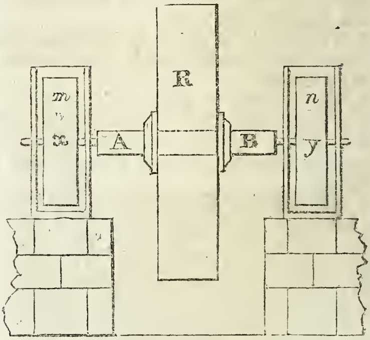
If we suppose, for example, that the weight of a wheel, whose iron gudgeons move in bushes of brass, is 100 pounds, then the friction arising from both its gudgeons will be equivalent to 25 pounds: if we suppose also that a force equal to 40 pounds is employed to impel the wheel, and acts in the direction of gravity, as in the cases of overshot-wheels, the pressure of the gudgeons upon their supports will then be 140 pounds, and the friction 35 pounds. But if the force of 40 pounds could be applied in such a manner, as to act in direct opposition to the wheel's weight, the pressure of the gudgeons upon their supports would be 100, minus 40, or 60 pounds, and the friction only 15 pounds. It is impossible, indeed, to make the moving force act in direct opposition to the gravity of the wheel, in the case of water-mills; and it is often impracticable for the engineer to apply the impelling power but in a given way: but there are many cases in which the moving force may be exerted, so as not to increase the friction, which arises from the weight of the wheel.

A contrivance for diminishing friction by rendering an axis of rotation unnecessary, is shown in the following figure.



Where A is a cylindrical wheel, without an axis of rotation, but turned by the rope *r r*, passing round a groove in its circumference. The wheel A is supported by the three wheels, or rollers *w*, *w*, *w*, which have a groove hollowed out upon their circumference.

Another method of diminishing friction, proposed by M. Gaston de Thiville, is shown in the following figure.



The wheel R has two hollow cylinders, *m*, *n*, fixed to its axle A B. These cylinders are made to float in boxes filled with water in such a manner, that the gudgeons pass through the boxes of water, so as to be water tight without preventing their rotation. The weight of the wheel is thus supported upon the floating cylinders, and it is kept in its place by the gudgeons *x*, *y*.

As it appears from the experiments of Coulomb, that the least friction is generated when polished iron moves upon brass, the gudgeons and pivots of wheels, and the axles of friction rollers, should all be made of polished iron; and the bushes in which these gudgeons move, and the friction wheels, should be formed of polished brass. In small and delicate machinery, the cups or planes which support pivots, or upon which knife-edges rest, as in balances and pendulums, should be made of garnet in preference to any other substance.

When every mechanical contrivance has been adopted for diminishing the obstruction which arises from the attrition of the communicating parts, it may be still farther removed by the judicious application of unguents. The most proper for this purpose are swine's grease and tallow, when the surfaces are made of wood; and oil when they are made of metal. When the force with which the surfaces are pressed together is very great, tallow will diminish the friction more than swine's grease. When the wooden surfaces are very small, unguents will lessen their friction a little, but will be greatly diminished if wood moves upon metal greased with tallow. If the velocities, however, are increased, or the unguent not often enough renewed, in both these cases, but particularly in the last, the unguent will be more injurious than useful. The best mode of applying it, is to cover the rubbing surfaces with as thin a stratum as possible, for the friction will then be a constant quantity, and will not be increased by an augmentation of velocity.

In small works of wood, the interposition of the powder of black lead has been found very useful in relieving the motion. The ropes of pulleys should be rubbed with tallow, and whenever the screw is used, the *square threads* should be preferred.

In order to apply unguents to the communicating parts of machines, various contrivances have been adopted. The spindles of trundles have been made hollow, to contain oil, so that when they had a horizontal position, they allowed it to drop from small apertures upon the wheel below, by which they were driven.

As we have now considered the subject of friction under each of the heads mentioned at page 212, we shall conclude this article by stating a few of the effects of this force which have not yet been noticed.

The distance to which a given body will be moved by percussion, in opposition to friction, is as the square of the velocity communicated to it, or the distance will be proportional to the square of the velocity. On this principle, some paradoxical appearances may be explained, which are not so easily accounted for on any other. When a carpenter, for example, would drive the handle of an axe into the head, he strikes against the handle after it is slightly inserted into the head, holding it loosely in his hand, without any firm support, and even the head *downward;* at each blow the handle is driven farther than if the blow had been given to the head itself. The reason is, that the handle is the lighter body, and, therefore, the velocity which a blow communicates to it, is greater than that which the same blow would communicate to the head. The friction is of course more effectually overcome.

A nail, too, is driven by a blow of no great force, into a piece of wood where the mere friction is sufficient to retain it against a great force applied to draw it out.

The same thing is exemplified in the method now practised, of raising a stone by an iron plug, driven into a circular hole cut in the stone. A few blows of a small hammer are sufficient to fix the plug, so that it will serve not only to suspend the stone, though of several hundred pounds weight, but even to draw it out of the earth, in which it is perhaps sunk to a considerable depth. Such is the effect of percussion, that a few blows of a hammer, given obliquely to the plug, are sufficient to disengage it from the stone. The stones on which this experiment has been made, have always possessed great hardness and cohesion.

Though friction destroys motion and generates none, it is of essential *use* in Mechanics. It is not only the cause of stability in the structure of machines; but it is necessary to the exertion of the force of animals.

A nail, a screw, or a bolt, could give no firmness to the parts of a machine, or of any other structure without friction. Animals could not walk, or exert their force in any way without the support which it affords. Nothing would have any stability but in the lowest situation possible, and an arch that could sustain the greatest load when properly distributed, might be thrown down by the weight of a single ounce, if not placed with mathematical exactness at the very point it ought to occupy.

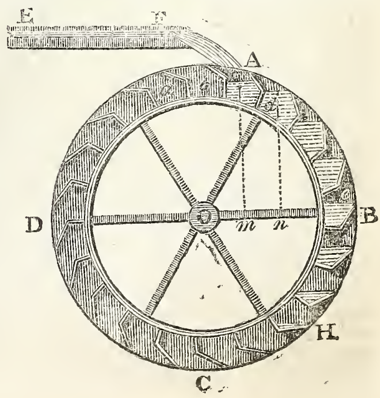
HYDRAULICS.

Having now given a very full account of the various instruments and machines employed for raising water from a lower to a higher situation, we shall here enter upon the important subject of water wheels. Of these there are various kinds; but they are usually classed under the following heads; viz. those that are moved by the weight of water, those that are moved by the *impulse* of water, and those that are moved by the *re-action* of water.

When a *wheel* receives the water into buckets, at or near its highest point, it is put in motion by the *weight* of the water with which it is loaded on one side, and it is then called an Overshot-wheel.

CONSTRUCTION OF OVERSHOT-WHEELS.

An overshot-wheel of the common kind, is represented as in the following figure.



Where A B C D is the rim of the wheel, having a number of buckets *a*, *b*, *c*, *d*, arranged round its circumference. When the wheel is in a state of rest upon its axis O, and water is introduced into the bucket *c* from the horizontal mill course or canal E F, the weight of the water in the bucket, acting at the end of a lever equal to *m* O, puts the wheel in motion in the direction *c d*. When the subsequent bucket *b* comes into the position *c*, it is also filled with water, and so on with all the rest. When the bucket *c* reaches the situation of *d*, its mechanical effect to turn the wheel is increased, being now equal to the weight of water acting at the end of a lever *n* O, equal to the distance of its centre of gravity *d*, from a vertical line passing through the axis O, so that the mechanical effect of the water in the bucket increases all the way to B, and of course diminishes while the buckets are moving from B to C.

The buckets, however, between B and C, have not the same power upon the wheel as those between A and B; for the water begins to fall out of the buckets before they approach to B, and are almost completely empty when they reach the point H. The construction of the buckets, therefore, as shewn in the figure, is very improper, as it not only allows the water to escape before it has reached the point B, where its mechanical effect is a maximum; but also to escape completely, long before they have reached the lowest point C of the wheel. The power, therefore, of an overshot-wheel must depend principally upon the form which is given to the buckets, which should always be fullest when they are at the point B, and should retain the water as long as possible. If the buckets were to consist of a single partition in the direction of the radii of the wheel, all the water would escape from the buckets before they passed the point B on a level with the axis O.

It has in general been assumed by writers on water wheels, that the diameter of overshot-wheels should always be less than the height of the fall of water by which it is to be put in motion, and various ratios have been assigned between the height of the fall and the diameter of the wheel. The Chevalier de Borda has shewn, that overshot-wheels will produce a maximum effect when their diameter is equal to the greatest height of the fall, but that a slight diminution of the wheel's diameter produces only a very small diminution of the maximum effect. If the height of the fall, for example, is 12 feet, and if the diameter of the wheel is made only 11 feet, the effect is diminished only $\frac{1}{12}$. This theoretical result has been confirmed by the admirable experiments of Mr. Smeaton, who found, "*that the higher the wheel is in proportion to the whole descent, the greater will be the effect*;" because, as he remarks, "it depends less upon the impulse of the head, and more upon the gravity of the water in the buckets; and if we consider how obliquely the water issuing from the head must strike the buckets, we shall not be at a loss to account for the little advantage that arises from the impulse thereof, and shall immediately see of how little consequence this impulse is to the effect of an overshot-wheel."

If the diameter of the wheel were equal to the whole height of the fall, the water would be laid in the buckets without having acquired any velocity; so that a portion of the power of the wheel would be spent in dragging this inert mass into motion, and also by the impulse of the buckets against the water, which will dash a part of it over the wheel. Hence, it is necessary, that the difference between the head of water and the diameter of the wheel should be such, that the water may acquire in its descent through that space a velocity a little greater than that of the circumference of the wheel. In this view of the subject, the water should fall through a height of $2\frac{1}{2}$ or 3 inches per second, in order to acquire the velocity of the wheel; and therefore the diameter of the wheel should be only 3 inches less than the height of the fall.

The determination of the diameter of an overshot-wheel, as given by Borda, Smeaton, Robinson, and other Authors, is founded upon the assumption, that it never should exceed the height of the fall. Let us suppose that we have a fall of 12 feet, and that the wheel should have a diameter of 11 feet according to Borda, then it appears to us, that a great advantage will be derived from making the wheel 15 feet. Now it is obvious, that the advantage of using the 15 feet wheel is, that we apply the water where it will act most perpendicularly to the line O D, in the foregoing figure, or the radius of the wheel; whereas the disadvantage of such a wheel is, that it begins to lose its water much sooner than the small one. We differ in opinion from Robinson when he says, that the loss of power in the latter case exceeds what is gained in the former case; but we shall admit that it is so, and still maintain the superiority of the 15 feet wheel. When the wheel has a diameter less than the height of the fall, any augmentation of the quantity of water discharged by the mill course is of no use in increasing the effect of the wheel. The issuing water indeed acquires a velocity greater than it usually has, but this additional velocity is injurious to the motion of the wheel instead of being of any advantage. In the case of a 15 feet fall, however, when the water rises 1 or 2 feet above its usual level, we have it in our power, by a particular form of the delivering sluice, to introduce this water upon the wheel 1 or 2 feet higher up the wheel, so that we are actually enabled to increase the height of the fall by this quantity.

From a series of experiments on overshot-wheels, by M. Deparcieu, and published in 1754, he has concluded, that most work is performed by an overshot-wheel when it moves slowly, and that the more we retard its motion by increasing the work to be performed, the greater will be the performance of the wheel. These experiments were made with a wheel 20 inches in diameter, and having 48 buckets. Cylinders of different diameters were placed upon the axle, and the effect of the wheel under different velocities was measured by the height to which it raised a weight suspended to a rope, which was wound round the different cylinders; and the general result was, that the slower the wheel turns, the greater is the effect, or the height to which the weight is raised.

In opposition to these results, the Chevalier D'Arcy maintained, that there is a certain velocity when the effect is a maximum; and he has shewn, from a comparison of Deparcieu's experiments with his own formulæ, that the wheel never moved with such a small velocity as would have given the maximum effect, and that if he had increased the diameter of his cylinders, he would have found that there was a velocity when the maximum effect began to diminish.

The experiments of Smeaton afford an excellent confirmation of the preceding reasoning. The wheel which he used was 25 inches in diameter. The depth of the buckets or of the shrouding was 2 inches, and the number of buckets 36. When it made about 20 turns in a minute, the effect was nearly the greatest. When the number of turns was 30, the effect was diminished $\frac{1}{20}$th part. When the number was 40, the diminution was $\frac{1}{4}$th; when the number was less than $18\frac{1}{4}$ its motion was irregular; and when it was loaded so as not to be able to make 18 turns, the wheel was overpowered by its load.

"It is an advantage in practice," says Mr. Smeaton, "that the velocity of the wheel should not be diminished farther than what will procure some solid advantage in point of power; because, *cæteris paribus*, as the motion is slower the buckets must be made larger; and the wheel being more loaded with water, the stress upon every part of the work will be increased in proportion. The best velocity for practice, therefore, will be such as when the wheel here used made about 30 turns in a minute; that is, when the velocity of the circumference is a little more than three feet in a second.

Experience confirms, that this velocity of three feet in a second is applicable to the highest overshot-wheels as well as the lowest; and all other parts of the work being properly adapted thereto, will produce very nearly the greatest effect possible; however, this also is certain from experience, that high wheels may deviate farther from this rule before they will lose their power by a given aliquot part of the whole, than low ones can be admitted to do; for a wheel of 24 feet high may move at the rate of six feet per second without losing any considerable part of its power; and, on the other hand, I have seen a wheel of 33 feet high, that has moved very steadily and well with a velocity but little exceeding two feet."

The experiments of the Abbé Bossut afford the same results. He used a wheel three feet in diameter. The height of the buckets was three inches, their width five inches, and their number 48; and the canal which conveyed the water furnished uniformly 1194 cubic inches in a minute. When the wheel was unloaded, it made $40\frac{3}{4}$ turns in a minute.

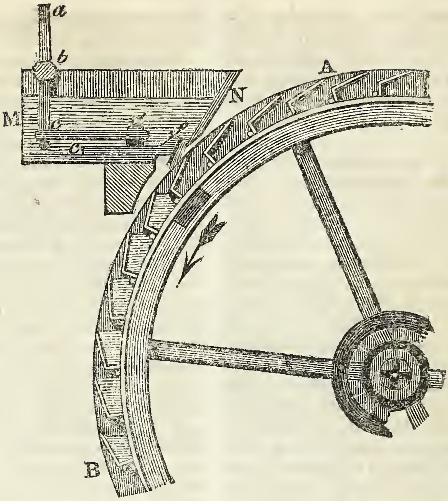
In comparing the relative effects of water wheels, the Chevalier de Borda maintains, that an overshot-wheel will raise through the height of the fall a quantity of water equal to that by which it is driven; while Albert Euler affirms, that the effect is greatly inferior to this. The experiments of Mr. Smeaton shew, that when the heads and quantities of water are least, the ratio between the power and the effect at the maximum is nearly as 4 : 3; but when the heads and quantities of water were greater, it is as 4 : 2; and by a medium of the whole, it is as 3 : 2. When the powers of the water, computed for the height of the wheel only, are compared with the effects, they observe a more constant ratio, the variation being only between the ratio of 10 : 8·1 and 10 : 8·5. Hence the ratio of the power, computed upon the height of the wheel only, is to the effect, at a maximum, as 10 : 8, or as 5 : 4 nearly, and the effects, as well as the powers, are as the quantities of water and perpendicular heights multiplied together respectively.

The form of the delivering sluice, and the method of introducing the water into the buckets, will be best explained in the description of different overshot-wheels.

SMEATON'S IMPROVED OVERSHOT-WHEEL.

Mr. Smeaton constructed a wheel which he considered as of an improved form.

In the following figure A B represents this wheel, and M N the extremity of the mill course, where the water is delivered into the buckets.



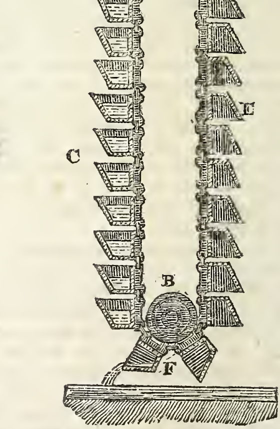
The vertical lever *a b c* turning round *b* as a centre, gives motion to the horizontal arm *c d*, and causes one of the shuttles *e f* to advance or recede; in consequence of which, the aperture on the right hand of *f* may be either increased or diminished, for the purpose of regulating the supply of water which the wheel may require. An iron bolt goes through the bottom of the trough between the two shuttles, and is intended to prevent the bottom from sinking by the weight of the water. From the form of the aperture at *f*, it will be seen that the water will glide easily into the buckets without any waste. In both these machines, the water is turned back on the near half of the wheel; the consequence of which is, that the resistance of the lower water is removed, as it runs off in the same direction with the motion of the wheel.

DOUBLE OVERSHOT-WHEEL WITH A CHAIN OF BUCKETS.

When there is a very small supply of water falling from a very great head, the overshot-wheel, which it is necessary to employ is so large and expensive, and so apt to be injured from its unwieldy size, that few persons would be disposed to erect one. In circumstances like this, the double overshot-wheel, with a chain of buckets, is a most invaluable machine, not merely from the small price at which it can be erected, but from the great power which it possesses. A machine of this kind seems to have been first erected by M. Francini in 1668, in the garden of the king of France's old library. This machine of Francini was driven by waste of water, and raised water from a natural spring, by means of another chain of buckets fixed upon the same wheel.

M. Costar substituted a similar machine in place of the overshot-wheel; and more recently Mr. Gladstone's, an ingenious millwright at Castle Douglas, in Scotland, erected several in Galloway for the purpose of giving motion to threshing mills.

The double overshot-wheel is represented in the following figure,



where A and B are two rag wheels, as they are called, and C D E F a series of buckets fixed to an endless chain, whose links fall into notches in the circumference of the rag wheels. The water issuing from the mill course at M N, is introduced into the buckets on the side C. The descent of the loaded buckets on the side C puts the wheels A and B in motion, and the power is conveyed from the shaft of the wheel A to turn any kind of machinery. When the buckets reach F, they allow the water to escape, and ascending empty on the side E, they again return to the spout M N, to be filled as before. In this machine, the buckets have in every part of their path the same mechanical effect to turn the wheels, and they will not allow the water to escape till they have reached almost the lowest part of the fall.

This species of wheel possesses another advantage, which can be obtained from no other; namely, that by raising the wheel B, and taking out two or three of the buckets, it may be made to work when there is such a quantity of back-water as would otherwise prevent it from moving.

Dr. Robison, in his Dissertation on Water Works, published in the second volume of his *System of Mechanical Philosophy*, has described a machine of this kind, in which plugs, or horizontal float boards, are fixed to a chain. On the side C these plugs pass through a tube, a little greater in diameter than that of the floats, as it does in the case of a breast wheel, giving motion to the wheels A and B.

The double overshot-wheel is the best and the most economical which can be adopted for a small supply of water falling from a great height; but it is liable to get out of order, unless the chain which carries the buckets is made with great care and nicety.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF WILLIAM EMERSON.

William Emerson, a very eminent mathematician, was born May 14, 1701, at Hurworth, a village about three miles south of Darlington, on the borders of the county of Durham, at least it is certain he resided here from his childhood. His father, Dudly Emerson, taught a school, and was a tolerable proficient in mathematics; and without the benefit of his books and instructions, perhaps his son's genius might never have been unfolded. Besides his father's instructions, our author was assisted in the learned languages by a young clergyman, then curate of Hurworth, who was boarded at his father's house. In the early part of his life, he attempted to teach a few scholars; but whether from his concise method (for he was not happy in expressing his ideas), or the warmth of his natural temper, he made no progress in this profession; he therefore soon left it off, and satisfied with a small paternal estate of about 60 or 70 pounds a year, devoted himself to study, which he closely pursued in his native place through the course of a long life, being mostly very healthy, till towards the latter part of it, when he was much afflicted with the stone: towards the close of the year 1781, being sensible of his approaching dissolution, he disposed of the whole of his mathematical library to a bookseller at York; and on May the 26th, 1782, his lingering and painful disorder put an end to his life at his native village, in the eighty-first year of his age. In his person he was rather short, but strong and well-made, with an open countenance and ruddy complexion. He was never known to ask a favour, or to seek the acquaintance of a rich man, unless he possessed some eminent qualities of the mind. He was a very good classical scholar, and a tolerable physician, so far as it could be combined with mathematical principles, according to the plan of Keil and Morton. The latter gentleman he esteemed above all others, as a physician—and the former as the best anatomist. He was very singular in his behaviour, dress, and conversation. His manners and appearance were that of a rude and rather boorish countryman; he was of very plain conversation, and indeed seemingly rude, commonly mixing oaths in his sentences. He had strong natural parts, and could discourse sensibly on any subject; but was always positive and impatient of any contradiction. He spent his whole life in close study and writing books; with the profits of which he redeemed his little patrimony from some original incumbrances. He had but *one coat*, which he always wore open before, except the lower button; no waistcoat; his shirt quite the reverse of one in common use, no opening before, but buttoned close at the collar *behind;* a kind of flaxen wig, which had not a crooked hair in it; and probably had never been tortured with a *comb* from the time of its being made. This was his dress when he went into company. One hat he made to last him the best part of his lifetime, gradually lessening the flaps, bit by bit, as it lost its elasticity and hung down, till little or nothing but the crown remained. He never *rode*, although he kept a *horse*, but was frequently seen to lead the horse, with a kind of wallet stuffed with the provisions he had bought at the market. He always walked up to London when he had any thing to publish, revising sheet by sheet himself; trusting no eyes but his own, which was always a favorite maxim with him. He never advanced any mathematical proposition that he had not first tried in practice, constantly making all the different parts himself on a small scale, so that his house was filled with all kinds of mechanical instruments together or disjointed. He would frequently stand up to his middle in water while fishing, a diversion he was remarkably fond of. He used to study incessantly for some time, and then for relaxation take a ramble to any pot ale house where he could get any body to drink with and talk to. The Duke of Manchester was highly pleased with his company, and used often to come to him in the fields and accompany him home, but could never persuade him to get into a carriage. When he wrote his small treatise on navigation, he and some of his scholars took a small vessel from Hurworth, and the whole crew soon got swampt; when Emerson, smiling and alluding to his treatise, said "They must not do as I do, but as I say." He was a married man; and his wife used to spin on an old-fashioned wheel, of which a very accurate drawing is given in his mechanics. He was deeply skilled in the science of music, the theory of sounds, and the various scales both ancient and modern, but was a very poor performer. He carried that singularity which marked all his actions even into this science. He had, if we may be allowed the expression, two first strings to his violin, which, he said, made the E more melodious when they were drawn up to a perfect unison. His *virginal*, which is a species of instrument like the modern spinnet, he had cut and twisted into various shapes in the keys, by adding some occasional half-tones in order to regulate the present scale, and to rectify some fraction of discord that will always remain in the tuning. He never could get this regulated to his fancy, and generally concluded by saying, "It was a bad instrument, and a foolish thing to be vexed with."

Mr. Emerson's Works are too numerous to be inserted here.

SYMPATHETIC INKS.

Sympathetic ink is a substance with which writings may be formed, which are *invisible* till they are subjected to some process, which immediately renders the whole distinct. This purpose was fulfilled among the ancients by means of milk, or some other viscous substance, which was rendered legible by means of soot thrown over the writing; part of it adhering wherever the lines were drawn, while from every other part it was blown entirely off.

There are some articles employed for this purpose, which are rendered visible by the addition of a substance which acts chemically. The materials of writing ink may, for example, be employed in a separate state. Invisible words may be first written with a solution of the sulphate of iron. If a rag, dipped in a decoction of galls, be drawn over them, they become immediately legible. If this be afterwards rubbed over with sulphuric acid, it is effaced. But the application of a saturated solution of potassa, will make it re-appear like yellow writing.

The golden sympathetic ink consists of a solution of gold in nitro-muriatic acid, diluted with six times its quantity of water. Letters traced with this are invisible; but when a similar solution of tin is applied to them, the writing appears in the form of beautiful purple letters.

Nitromuriatic acid is now capable of effacing them, and the re-application of the muriate of tin will restore them. Letters made with the muriate of gold, indeed, become spontaneously visible when exposed to the air. This, however, requires several days, and, if kept closely shut up, they remain invisible for two or three months. The acid evaporates, and leaves a violet oxide or submuriate. Nitrate of silver affords invisible letters, which become black by long exposure.

There are many sympathetic inks which are rendered visible by exposure to a fire. Solutions of muriate of ammonia, and various other neutral salts, act on paper by means of heat, in such a way as adapts them to this use; but the letters become, in process of time, confused and illegible.

The best sympathetic inks are those made from ores of arsenic, bismuth, or cobalt. Diluted nitric acid is poured on arsenic ore, and afterwards carefully decanted, treated with nearly half the quantity of dried muriate of soda, and evaporated. Letters or figures formed with this are invisible till held near the fire, which renders them visible, and of a beautiful blueish green colour. This disappears again when it is removed from the fire. Allum, with the sulphate of soda, used instead of muriate of soda, renders the substance red. Borate of soda, or nitrate of potassa, also makes the letters appear red.

The nitro-muriate of cobalt forms a similar ink, which appears on exposure to heat, and disappears in the cold. The heat applied to it, however, must not exceed a certain strength, otherwise the letters become permanently visible both in heat and cold. These inks are employed for making amusing landscapes, in which the trees acquire a summer foliage as often as they are brought near a fire.

A sympathetic ink may be obtained from fresh urine, evaporated, then dissolved in nitric acid, and saturated with ammonia or its carbonate. Lines drawn with this become visible, of a fine red, on exposure to a gentle heat. Sulphate of zinc applied to them gives them a rich yellow. This ink must be applied, however, immediately after it is formed. It becomes deteriorated in so short a time as twenty minutes.

ARCHITECTURE.

GOTHIC ARCHITECTURE.

After having described the five Orders, it will naturally be expected that we should say something of the *Gothic* style; we shall therefore give a general view of the distinguishing features of this species of Architecture.

The attention to Gothic architecture having only been lately revived, the practice has not hitherto been digested into so systematic order as the Greek or Roman; and it is not a little extraordinary, considering that during the ages in which it was extensively practised, its operations were directed by men of science and literary habits, that no written rules have been discovered in the religious houses, which were then the only depositories of knowledge. This has led Mr. Knight, and other men of observation, to assert, that each architect proceeded independently of rules, and worked in the manner, which to him appeared best calculated to produce a striking effect, and that it was in consequence of the absence of determined rules, that this school rose to the degree of sublimity it attained. This is denied by other able and enlightened men, who have paid much attention to the subject, especially Dallaway, Milner, and Hawkins, who maintain, that although few arranged rules and proportions have been published in books, yet architects and workmen were constantly guided by known rules agreeable to the prevailing mode. It is evident, although not so rigidly confined as the Egyptian, that the Gothic architects were fully as much limited as the Roman; for the contrast between the massy plain Norman style, and the latter or florid Gothic, is not greater than what was produced by varying from the plainness, simplicity, and oblong forms of the ancient Greek temples, to the circular, delicate, and highly ornamented edifices of the latter Roman.

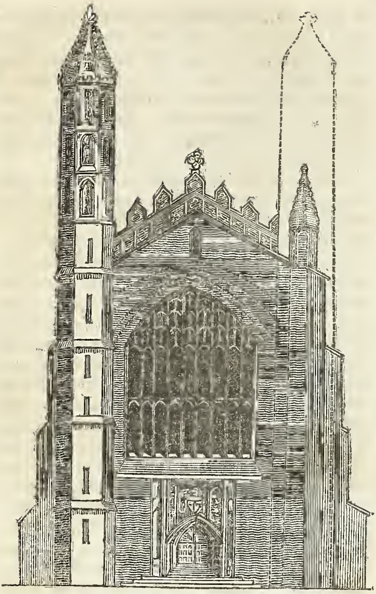
The Gothic style having been employed almost exclusively in edifices appropriated to the purposes of the Christian religion, the outlines of the ground plan have almost uniformly been a cross. In the Greek and Roman oblong temples, the ratio of the length and breadth was determined by the number of columns placed at nearly equal distances along the ends and sides, while that of the height was regulated by the diameter of the column; but in the Gothic, where seldom any columns have been placed on the outside of the edifice, and the use of arches proving a relief from constraint within it, it is alleged, that the proportion of the length to the breadth has been determined by triangles and squares. Of this, Mr. Hawkins, in his History of the Origin and Establishment of Gothic Architecture, (chap. 10), has produced an early instance from Cæsar Cæsarianus, a celebrated architect of Milan, who, in an elaborate commentary annexed to his translation of Vitruvius, has explained the principles of Gothic architecture.

With regard to the form of the *essential parts*, they are mostly defined in the following description of the three orders of Architecture, as given by Dr. Milner.

The *first order* is characterised during its formation; that is to say, till near the latter end of the 12th century, chiefly by its acute arch (its pillars and other members being frequently Saxon), but after its formation, not only by the narrowness and acuteness of its arch, but also by its detached slender shafts, its groining of simple intersecting ribs, its plain pediments without crockets or side pinnacles, and its windows, which were either destitute of mullions, or have only a simple bisecting mullion, with a single or triple trefoil, quatrefoil, or other flower, in the head of them. Of this order are the east end of Canterbury, the west end of Lincoln, and the whole of Salisbury Cathedrals, besides the transepts of York Minster and Westminster Abbey.

The *second order* is marked, not only by the fine turn of its perfect equilateral arch, but also by the cluster columns, being, for the most part, formed each course out of the same stone; by the elegant, but not over crowded tracery of its windows and groining; by its crocketted pinnacles, tabernacles, and pediments, the latter of which, towards the conclusion of the fourteenth century, were made with an ogee sweep towards the arch they covered. To this order belong the nave of Westminster Abbey, the nave and choir of York Minster, the naves of Winchester, Exeter, and Canterbury Cathedrals, Wykeham's two Colleges, St. Stephen's Chapel, &c.

The *third order* is known, not only by the flatness of the point of the arch, but also by its numerous, large, and low descending windows, together with the multiplicity and intricacy of its tracery; by its pendents from the roof; by the minuteness and profusion of its ornaments, both exteriorly and interiorly; by its fan-work and numerous shields and devices on the ceiling. To this order belong St. George's Chapel, Windsor, King Henry the Seventh's Chapel, Westminster, and King's College Chapel, Cambridge, of which the following is an elevation, showing on one side the buttresses, the tower being supposed to be removed, and on the other the tower; which not only supplies the place of a buttress at the end, but assists also in supporting a considerable portion of the thrust in the direction of the length of the Chapel.



One of the finest features of Gothic architecture, and which, in many instances, still forms the most striking ornaments of our cities, is the tall tapering spire, which was first built of wood by the Normans, and afterwards in stone early in the 13th century. In the course of the 14th and 15 centuries, they were greatly increased in number.

MEDICAL PUMP.

Having received a drawing and description of an instrument called the Medical Pump, we have embraced the first opportunity of laying them before our readers.

"The instrument," says the Inventor, "is here represented as performing some of the operations in which it is used. The cylinder of the pump or syringe (made in brass and in silver) is about seven inches in length, and one inch in diameter, contracted at its apex into a small opening for receiving the extremity of an elastic tube, which is passed into the stomach. Within this opening is a chamber containing a spherical valve, which, by rising into the upper part of the chamber where a vacuum is formed by elevating the piston, admits the atmosphere (or whatever it may be desirable to operate upon) to pass freely into the syringe, but as soon as the piston is depressed, the contents of the syringe presses the valve close upon the aperture, and prevents its escape through the opening by which it was received.

To give exit to the contents of the syringe, a side branch is constructed, furnished with a valved chamber similar to the one above described; but so placed as to act in direct opposition to it, so that when the syringe has been filled from the extremity, and pressure is made by depressing the piston, the fluid closes the lower valve and opens the lateral one, and consequently escapes through the latter aperture. To facilitate the operation of the instrument, a small pipe communicates with the upper extremity of the syringe, which gives free ingress and egress to the atmosphere during the action of the piston, a circumstance essentially necessary in causing the instrument to work easily and perfectly. Thus it is seen, that the syringe is furnished with two valvular apertures, through *one of which* the fluid to be injected is pumped from the vessel that contains it, and then immediately forced through *the other* into the part destined to receive it: this double operation is effected by repeated strokes of the piston, which slides so easily that an infant may use it, and any quantity of fluid may be thus made to pass through the syringe.

In cases of obstruction and constipation of the bowels, the injection of fluids is of the utmost importance; and as this instrument gives to the surgeon the means of throwing into the intestinal tube any quantity he may think proper with a distending power, sufficient even to overcome the tone of the fibrous texture of the bowels themselves, it has been found by many experienced practitioners eminently successful in cases of this description. As a glyster apparatus in simple cases, and for domestic purposes, it possesses advantages over every other instrument hitherto invented, for it may be used by the patient himself with the greatest ease, safety, and convenience.

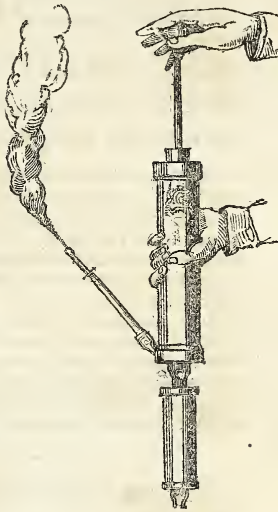
The patent syringe has been proved by the experiments of Mr. Scott and Mr. Jukes to be the most effective apparatus for removing poisons from the stomach that can be employed; and this opinion is corroborated by the testimony of Sir Astley Cooper, (see Lancet, No. 8, Vol. 1.) and the most eminent physicians and surgeons of Paris, before whom these gentlemen have lately performed the operation.

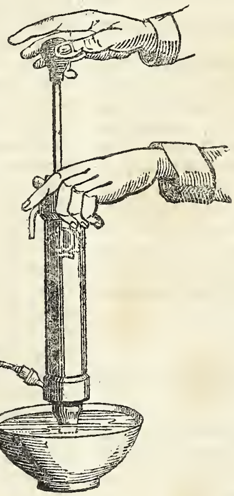
In cases of retention of urine, it frequently happens that in consequence of hæmorrhage and other causes the catheter becomes so obstructed that the bladder cannot be emptied: it was suggested by Dr. Cloquet, a celebrated surgeon of Paris, to effect this purpose by fixing a pump to the catheter. The patent syringe performs this operation with extreme facility, and has been honoured with the entire approbation of Dr. Cloquet. For injecting the bladder, which is an operation every day becoming more frequent, it is of course equally eligible.

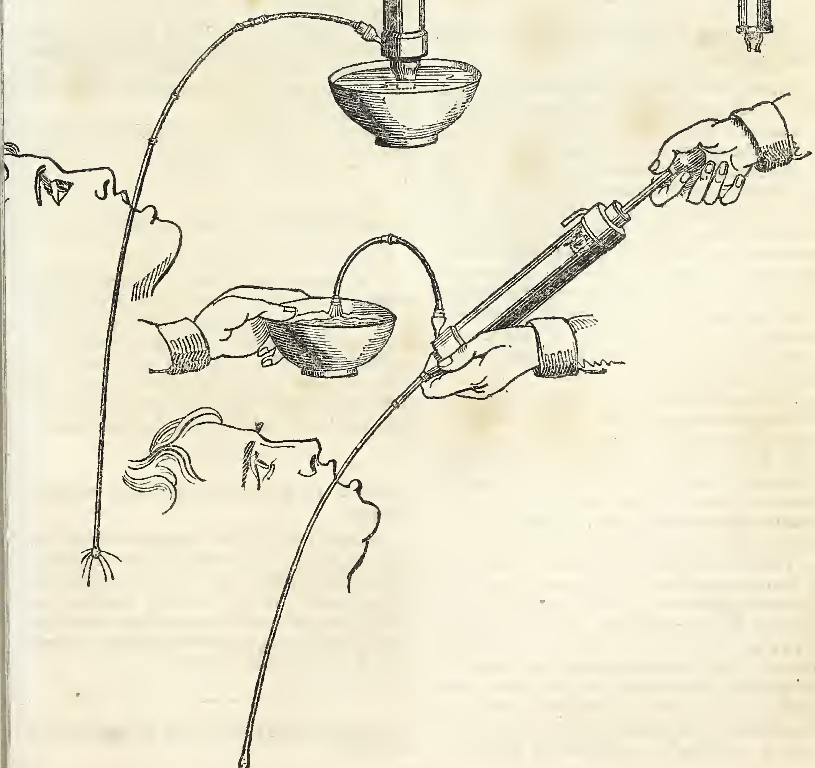
As an apparatus for conveying nourishment into the stomach of persons afflicted with stricture of the œsophagus, the patent syringe is found to possess obvious advantages.

This pump is also capable of being adjusted to cupping glasses, by which any degree of exhaustion can be made that the operator desires; and in the same manner it may be rendered a very effectual instrument for drawing the breasts of puerperal females. A small metallic canister has also been added for burning tobacco, as the syringe is found to be an effectual instrument for injecting tobacco fumes in cases of cholic, introsusception, hernia, &c.

The plate represents the instrument in the performance of three offices: 1st, that of injecting fluid into the stomach: 2dly, of withdrawing the contents of the stomach; and 3dly, of introducing tobacco fumes into the bowels. The inventor and patentee of this useful instrument is a Mr. Read, No. 30, Bridge-house Place, Newington Causeway, who has the satisfaction of knowing, that his labours have been crowned with success in numerous cases of diseases, which had resisted all other means, and of finding that many valuable lives have been saved from the destructive effects of poisons, by the timely application of this product of his industry and ingenuity."







SOLUTIONS OF QUESTIONS.

Quest. 34, *answered by* J. C. S. *(the proposer)*.

Put A = 1·8 the height of the segment, F = the content of ditto, B = the height of the frustrum, C = 7·2 the base or diameter of the water's surface, D = diameter of the ball G = content of ditto, and E = ·523598.

Here $\frac{C}{2} = 3{\cdot}6$ and $\frac{3{\cdot}6^2 + A^2}{A} = \frac{16{\cdot}2}{1{\cdot}8} = 9 = D$; and $D^3 \times E = 729 \times E = 381{\cdot}7029 = G$; and $\frac{C^2}{2} = 3{\cdot}6^2 \times 3 = 38{\cdot}88 + (3{\cdot}6)^2 = 90{\cdot}72$ which multiplied by 7·2 = 653·184, and this multiplied by ·5236, gives 342·0058 inches, the quantity of water forced into the ball, which, subtracted from G or 381·7029 ÷ 39·6971 = 39·6971 = F = the air left in the ball—and G ÷ F = $9\frac{10}{13}$ rarer the air was, within the receiver, than it is without. (See the fig. page 67.)

Mr. J. Barr also states the quantity of water, forced into the ball, at 342·066 inches, but does not show how he found it to be so; he has also omitted to state the rarity of the air in the ball.

Quest. 35, *answered by* Mr. J. Snart, *Tooley-street.*

Taking the specific gravity of cast iron at 7·207, sea water at 1·025, distilled water at 1·000, and dry oak at ·920, (that being the mean of ·915 and 9·25.) Then, as a cubic foot of distilled water = 62·5 lbs. = 1000 ozs. avoirdupoise, this last weight × ·5236 = 32·725 lbs. = the weight of a solid sphere of distilled water 12 inches diameter, which × 7·207 = 235·849075 lbs = a sphere of *cast iron* (if solid) of same dimensions, and a similar sphere of *sea* water = 33·543125 lbs. Consequently 235·849075 minus 33·543125 (quantity of water displaced) = 202·30595 lbs. tendency to *sink* the cone's base in sea water.

Again, the difference between the specific gravities of sea water (1·025) and dry oak (·920) = ·105 = 6·5625 = 6 lbs, 9 ozs. per cubic foot. Therefore 202·30595 (weight of the ball) ÷ 6·5625 = 30·8276 = the cubic feet of a cone of dry oak, competent to counteract the tendency of descent induced by the cast iron sphere.

Then as the solid content of a cone is = $\frac{1}{3}$ that of a *cylinder* of the *same* base and altitude; 30·8276 × 3 = 92·4828 = the solidity of the cylinder. And 92·4828 ÷ ·7854 = 117·7525 = the quadrangular prism, which ÷ 6 (the stipulated height) = 19·625416· the square root of which is = 4·43 feet = 4 feet $5\frac{1}{6}$ inches, being the diameter of the base of a solid cone of dry oak 6 feet high, competent to sustain a cast iron ball 12 inches diameter of 202 lbs. 5 ozs. in equilibrio with sea water.

N.B. As specific gravities are liable to varieties, so shades of difference sometimes may exist in solutions of this kind of problems without error. The iron ball, as well as the cone, is here supposed to be *solid*, and without *hoops*, &c.; therefore Mr. G. from his local knowledge, will be able to appreciate the performance.

The observation contained in the above note of our intelligent correspondent, respecting specific gravities, is perfectly just; for we have received two other solutions to the above question, and in each, the specific gravity of *dry oak* is taken at 800, which we believe is nearer the truth than 920, at which it is taken in the above solution.

This difference has occasioned a material difference between the above answer and those sent us by the other two gentlemen who solved the question. The proposer (Mr. Graham), makes it 3·044 inches; and Mr. John Barr makes it 3·334 inches.

We have to remark respecting Mr. Barr's solution, that it is too *algebraic*. In questions where there are so many *known* quantities, and so few *unknown* ones, there can be no use for treating them in the form of *equations*.

We have also to remark that we wish Correspondents who have occasion to quote numbers, contained in tables, to refer to the "Artisan," when the tables are to be found in that work.

There is a very accurate table of specific gravities inserted at page 25. Edit.

QUESTIONS FOR SOLUTION.

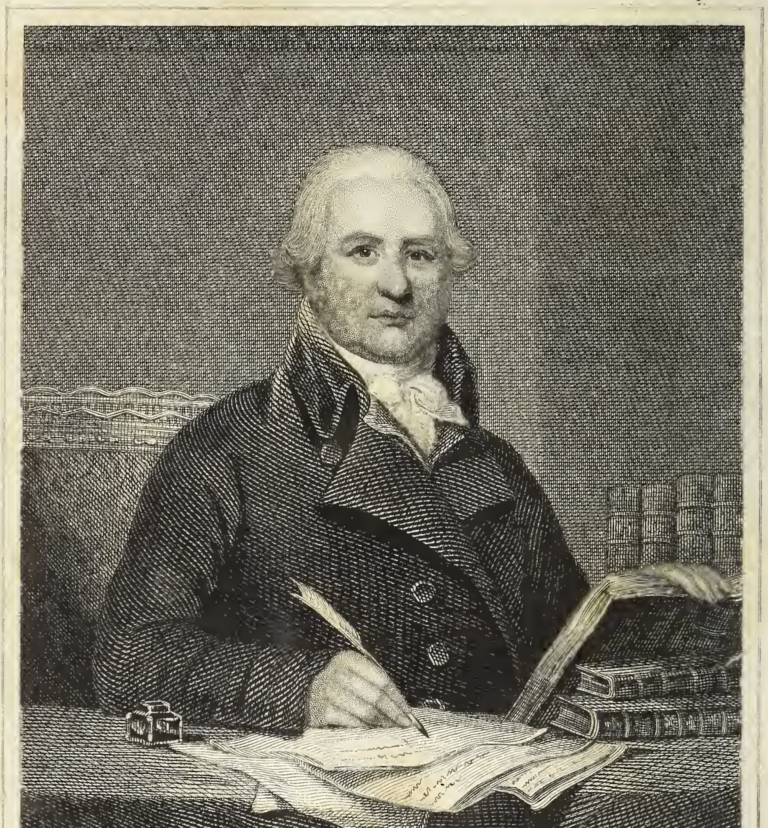
Quest. 40, *proposed by* G. G. C.

If a particle of a fluid, at any depth, press with a force equal to that which it would acquire in falling down a perpendicular space, equal to its depth below the surface; and if a ship has been bored by a 32 pounder, 8 feet below the surface of the water, what weight of water will rush in to the vessel, at the bore, in 10 minutes.

Quest. 41, *proposed by* Mr. Whitcombe, *Cornhill.*

Mr. Graham, in his late ascent with his balloon, says, "he was elevated $2\frac{1}{2}$ miles above the earth;" quære the quantity of square miles of the earth's surface he could have seen with an excellent telescope at that elevation, admitting the air favorable for such observation?

In page 237—line 23—col. 2, for Declaration *read* Declination.



CHARLES HUTTON, LL.D, F.R.S.

London; Published by Hodgson & Co. 10, Newgate Street.

—1824—

MEMOIR OF THE LIFE OF THE LATE DR. HUTTON.

CHARLES HUTTON, LL.D and F.R.S. of London and Edinburgh, also an honorary member of several other learned societies, both in Europe and America, was born at Newcastle-upon-Tyne, on the 14th of August, 1737. He was descended from a family in Westmoreland, who had the honour of becoming connected, by marriage, with that of Sir Isaac Newton. His father, who was a viewer or superintendant of mines, gave his children such education as his circumstances would permit, which was confined to the ordinary branches; but Charles, the youngest of his sons, (the subject of this memoir) early manifested an extraordinary predilection for mathematical studies, in which he made considerable progress, while yet at school, with very little aid from his master; for, like most other eminent mathematicians, he was in a great measure self-taught. After the death of his parents, which took place at an early period of his life, he determined on undertaking the profession of a teacher, and commenced his labours at the neighbouring village of Jesmond, before he was twenty years of age; his master, who was a clergyman, having, upon being presented to a living, resigned the school in his favour.

In the year 1760, Dr. Hutton removed to Newcastle, where he soon experienced great encouragement; and, among his earliest pupils, was the present Lord Chancellor. We here call him Doctor prematurely, he not having received the diploma of LL.D. until the year 1779, when that honour was conferred upon him by the University of Edinburgh; but, as it is the title by which he is best known in the scientific world, we thus early adopt it.

It appears, that neither the duties of his profession, nor the cares of an increasing family, interrupted his favourite studies, as he devoted all his leisure hours to mathematical pursuits. In 1764 he published "*A Treatise on Arithmetic and Book-keeping*," which soon passed through numerous editions, and is still held in high estimation. His next publication was "*A Treatise on Mensuration, both in theory and practice*," and is considered the most complete work on the subject ever published. It established his reputation as a mathematician, although numerous proofs of his superior talents and acquirements had been already manifested, by his able solutions of mathematical questions in various scientific journals. Among these repositories, the celebrated Almanac, under the title of the Ladies' Diary, particularly attracted his attention. This work had been conducted with great ability, from its commencement in 1704; numerous learned correspondents contributing, annually, curious mathematical questions, and answers, with enigmas, &c. Dr. Hutton collected the Diaries of fifty years, and republished their Questions and Solutions, in five volumes, with notes and illustrations, which form a very useful and interesting miscellany. He some time afterwards became the editor of the Diary, and conducted it for nearly half a century, with such ability and judgment, as greatly to increase the number of eminent mathematicians, and to enlarge the boundaries of useful science. Dr. Hutton's office of editor of this work, also afforded him an opportunity of procuring biographical notices of the most eminent of his correspondents: with which he afterwards enriched his Mathematical Dictionary, and his Abridgement of the Philosophical Transactions.

We should not neglect to notice here, that Dr. Hutton, about the year 1770, was employed by the magistrates of Newcastle, to make a survey of the town and the adjoining country, in order that a correct plan of it might be engraved and published. In this laborious undertaking, the Doctor gave great satisfaction, the plan having been executed with much beauty and accuracy.

On the 17th of November, 1771, the bridge of Newcastle was almost entirely destroyed, by a very great flood, which swelled the waters in the river about nine feet higher than the usual spring-tides. This event was the means of considerably increasing Dr. Hutton's mathematical reputation. Previous to commencing the repairs of the extensive damage which the bridge had sustained, it was desirable to endeavour to prevent, as far as possible, the recurrence of similar accidents; and the principal architects and civil engineers of the country were invited to furnish plans for the purpose. Dr. Hutton now, for the first time, directed his attention to the subject; and his suggestions were adopted, in preference to numerous others, which had been presented from various quarters. On the spur of the occasion, the Doctor drew up a Treatise on the Principles of Bridges, demonstrating the best mathematical curves for the arches, with the due proportion of the piers, &c.

It may here be remarked, that Dr. Hutton's early publications, particularly his

Mensuration, the Diarian Miscellany, and his Work on Bridges, were the means of rearing and bringing into notice the ingenious Mr. Bewicke of Newcastle, the most celebrated wood-engraver that the world has, perhaps, ever produced. Nor should it be forgotten, that, by Dr. Hutton's suggestions and observations, the art of printing has been very considerably improved.

In 1773, the situation of Mathematical Professor to the Royal Military Academy at Woolwich having become vacant, numerous gentlemen of the first eminence in science applied for the appointment; and, among the number, Dr. Hutton presented himself as a candidate. The office was in the gift of the Master-General of the Ordnance, and the strongest interest was made by various noblemen and gentlemen for their respective friends; but, to the honour of the then Master-General, Lord Viscount Townshend, nothing but superior qualifications were allowed to avail. His Lordship gave public notice, that merit alone should decide the preference, which must be determined by a strict and impartial examination. With this view, four eminent mathematicians were selected as examiners on the occasion; viz. Dr. Horsley, afterwards Bishop of Rochester, Dr. Maskelyne, the Astronomer Royal, Colonel Watson, the Chief Engineer to the East India Company, and the celebrated Mr. Landen.

Nothing could be more strictly impartial than the examination. The candidates were eight in number, and each was separately examined, not only in the principles, but in the history of mathematics. Several abstruse problems were afterwards given for solution; and, when the answers were received, the report of the examiners expressed high approbation of all the candidates, but gave a decided preference in favour of Dr. Hutton. This was, indeed, an unequivocal test of superior merit. The judicious determination of the Master-General, by conferring the appointment on Dr. H. was in a short time found to be most advantageous to the Institution. It is, indeed, well known, that Dr. Hutton raised the Royal Military Academy, from a state of comparative inferiority, to the highest degree of celebrity and national importance. To his steady and persevering conduct for thirty-five years, and his improvements in military science, his country is essentially indebted for the success of the British artillery and engineers in all parts of the world, during the last half century.

His removal from Newcastle to so distinguished a situation near the metropolis, and his election, soon after, as a fellow of the Royal Society, gave him new opportunities for the advancement and diffusion of the most useful knowledge; for, it should be observed, that, at all times, his attention was particularly directed to those branches of the mathematics which are most conducive to the practical purposes of life. In a short time, he became an important contributor to the Philosophical Transactions, which, from the specimens he gave, it is probable he would have enriched more than any other member either ancient or modern, had not a stop been put to his valuable labours by unfortunate dissentions in the Royal Society, which nearly gave a death-blow to that excellent institution.

It were tedious here to detail the subjects of the several papers which Dr. Hutton, in a few years, submitted to the Royal Society, especially as they may be seen in the Philosophical Transactions of that period: but two papers deserve particular notice, as the most useful and important that, perhaps had been communicated since the chair of that learned institution was filled by Sir Isaac Newton.

The first of these communications was on the "*Force of fired Gunpowder, and the initial Velocities of Cannon-balls.*" These results had been determined by a series of experiments, made with a new instrument of the Doctor's own invention; and, so sensible was the Royal Society of the value of the communication, that the annual gold prize-medal was immediately voted as due to Dr. H. and it was accordingly presented to him by the President, Sir John Pringle, with an address expressed in the most flattering terms.

The other paper just alluded to, among Dr. Hutton's communications, was on the subiect of the "*Mean Density of the Earth,*" a laborious work, deduced from experiments and surveys of the mountain of Schehallien, in Perthshire. This operation, which had always been considered a *desideratum* in the scientific world, was commenced in 1775, by order of the Royal Society, and chiefly under the direction of Dr. Maskelyne, the Astronomer Royal. After the dimensions of the mountain had been taken, and the deflections of the plumb-line ascertained with great accuracy, and verified by repeated experiments, the most difficult and important part of the undertaking yet remained to be executed; namely, the calculations and the deductions, which required profound science, as well as immense labour. The attention of the Royal Society was at once directed to Dr. H. as the person most competent to this arduous undertaking. He undertook the task; and, in the course of a year, presented his report, which will be found in the "*Phil Trans.*" of 1778, and 1821.

[*To be continued.*]

PNEUMATICS.

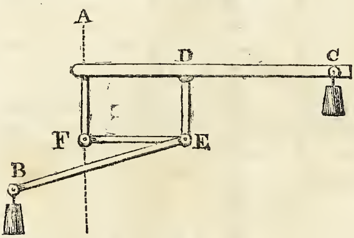
STEAM ENGINE.

As we have given a drawing and description of Mr. Watt's most improved Engine in a working state, and, likewise of some of its principal parts when separated from the others, we shall here resume this part of the subject by describing the contrivance which Mr. Watt fell upon for keeping the piston rods in a perpendicular or vertical position, both when ascending and descending.

This contrivance depends upon a geometrical theorem, and Mr. Watt's successful application of it to the practical purpose to which he has applied it, proves that he was not only a practical mechanic, but a theoretical mathematician.

The manner of producing the *parallel motion*, as this contrivance is termed, is by means of the frame Q: see fig. page 197, which is constructed thus.

Let C in the following figure represent the centre of the working beam,



and let an arm B E turn about the firm joint B and guide the end E of the frame or parallelogram A D E F, then if C D be taken a mean proportional to A D and B E, the other end F, carrying the rod of a piston, will describe a vertical and rectilineal line, as represented by the dotted line A.

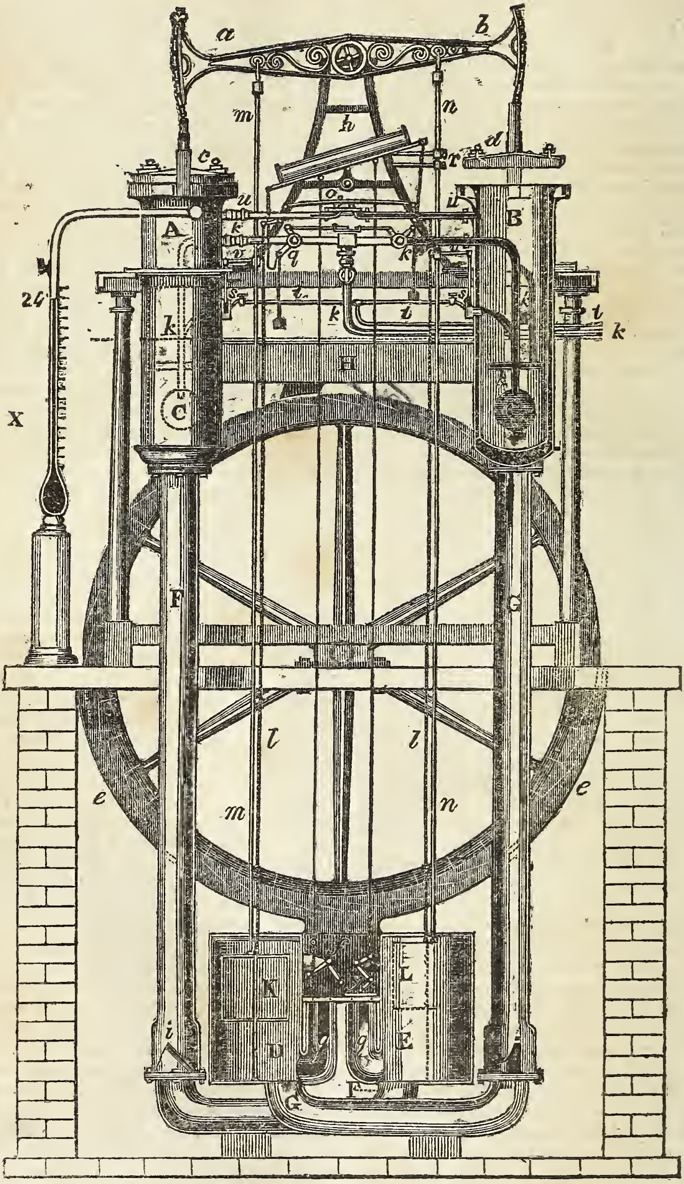
This beautiful contrivance was first employed in the engines erected at the Albion Mills, London.

We have now described the principal or most important parts of Mr. Watt's engine, represented at page 167, and though there are several other parts of that machine which we intend to notice, yet we must defer this till we enter upon the description of one of the high pressure engines, which have been erected still more recently; this, we shall do in another part of our work, and at present introduce to the notice of our readers an invention, which has just been completed by an ingenious engineer in London, which has every probability in its favour of effecting a complete revolution in the application of elastic fluids to the motion of machinery.

NEW GAS VACUUM ENGINE.

This is an engine similar in its effects to the steam engine; but differing from it so far as not to require the aid of steam at all. The immediate cause of motion in this engine is Hydrogen gas; which, as the Inventor and Patentee Mr. Brown says, in his description of it, "is introduced along a pipe into an open cylinder or vessel, whilst a flame, placed on the outside of and near a cylinder, is constantly kept burning, and at proper times comes in contact with, and ignites the gas therein; the cylinder is then closed air-tight, and the flame prevented from entering it. The gas continues to flow into the cylinder for a short *period* of time, and then is stopped off; during *that time* it acts, by its combustion, upon the air within the cylinder, and at the same time a part of the rarefied air escapes through one or more valves, and *thus a vacuum is effected;* the vessel or cylinder being kept cool by water. On the same principle, the vacuum may be effected in one, two, or more cylinders or vessels."

A vacuum having been thus produced, the motion of any form of machinery follows as a matter of course, and need scarcely be described; but we may be allowed to point out an instance or two in which it appears, that the *pneumatic* will be far more advantageous than the *steam* engine; while, with respect to POWER, the only assignable difference between them, will arise from the saving of friction in this, because the *power* of *each* is derived from the production of a vacuum —in one by means of the condensation of steam, in the other by means of the combustion of gas. The *respective powers* being thus easily compared, it only remains to calculate the advantages of the new engine, leaving our readers to decide between the two. The pneumatic engine is light and *portable;* averaging less than *one-fifth* the weight of a steam engine of the same power. Hence it is peculiarly advantageous for ships, as it saves tonnage both in its own weight and in the reduced quantity of fuel. The danger arising from the possibility of bursting a boiler in the steam engine (too many unfortunate instances of which are on record) is entirely obviated in the pneumatic engine; and the very small quantity of gas requisite shews, that no fears are to be entertained from any irregular ignition. The necessary fuel being reduced to a very small quantity, owing to there not being any *boilers*, the expense of working one of these engines (exclusive of the abatement of tonnage) will be very considerably less than that requisite for a steam engine, even of much less power.



The atmospheric pressure may be increased with perfect safety, by the extended dimensions of the cylinder. In the steam engines, from seven to eight pounds on the square inch, after deducting friction, is the limit of *available* power; in the pneumatic engines, we may estimate it at from 9 to 12. The mechanical means by which this invention can be applied to produce motion, may be very much varied; and any *rapidity* of motion that may be required, may be obtained. The combustion of gas is a more speedy operation than the condensation of vapour; and this fact alone would be sufficient to demonstrate the possibility of obtaining a more rapid motion than steam can afford. In the progress of chemical discovery, if (as is not at all improbable) a cheap mode of extracting hydrogen gas from water should be discovered, the pneumatic engines on board a ship or other vessel, would be every where supplied without the loss of an ounce of tonnage, at it is at present, they may extract the gas from oil, tar, &c. mater ials which occupy a very small space in proportion to the quantity of gas which they evolve.

But in order to give as accurate an idea as possible of this beautiful and truly original engine, we here present a very correct representation of it, which, along with the subjoined description of its several parts, will, we trust, render its construction and operation tolerably well understood, by all who take any interest in the improvement of the mechanical arts.*

The figure represents a front view of the engine as used for raising water and turning an overshot-wheel—the front part of the frame work being removed to give a clearer view of it.

A and B are the two cylinders in which the vacuum is affected alternately. A is represented shut and B open, the latter in section. These vessels are placed within two other cylinders, leaving a free passage between the inner and the outer cylinders, along which, when the vacuum is effected, the water rises, keeping both cool, and flows into the inner cylinder.

C and C are the entrances from the inner cylinders leading to the discharging valves, which are opened by the force of the water when it leaves the vessel, but which, being behind, are not shown in the drawing.

c and *d* are two caps or covers forming valves, and fitting close to the outer cylinders when shut, but leaving a passage under them for the water to flow through into A and B. In these caps are small valves, through which a part of the rarefied air escapes.

a b is the beam to which the covers are suspended by chains and rods.

D and E are two cylindrical water vessels open at their tops.

K and L are two cylindrical boxes or floats, air-tight, suspended in the last mentioned vessels, and are raised or depressed as the water in the vessels ascends or recedes.

F *i* F is a pipe leading from the cylinder A to the vessel E, and G *j* G is another pipe leading from the cylinder B to the vessel D. Through these two pipes the water is raised, and in them are clacks at *i* and *j*, to prevent the return of the water when the air is admitted into the cylinder.

f is a reservoir into which the water is received from the wheel along a case or trough *e e*, which surrounds the lower part of the wheel. From this reservoir the water flows alternately into the vessels D and E along the pipes *g g*, which are opened and closed by the movement of a slide *y* attached to two cranks.

k k k is the gas pipe leading from the gasometer, and terminating in gas burners in the inside of the cylinders. In this pipe are cocks to regulate the supply of gas.

t t t is a smaller gas pipe (leading also from the gasometer), and terminating at each end near to orifices in the cylinders. The gas being lighted at both ends of this pipe, will burn while the engine works.

u and *u*, are pipes along which the air is admitted into the cylinders alternately, by the movement of a slide-valve *o* over the entrances to the pipes.

m m and *n n* are rods attached to the beam, and leading into the vessels D and E. These rods are pushed up by the floats K and L as they rise, and thus the ends *a* and *b* of the beam are alternately raised.

v and *v* are arms (projecting from the rods *m* and *n*) to which are attached small rods, which move up and down two slide valves *s* and *s*. These slide valves close and open the orifices in the cylinders, towards which jets proceed from the gas burners.

h is an iron or glass tube half filled with mercury, fixed on a metal plate, from the ends of which proceed chains with weights at their ends, to open and shut the gas cocks alternately. The metal plate is raised and depressed by the projecting arms *r*, and to *h* are attached two long rods, which, when drawn up, operate on the cranks in the reservoir *f*, and move the slide *y* backwards and forwards.

X 24, is the mercurial gauge for ascertaining the power of the engine.

l and *l* are two chains attached to the floats K and L, and to the cranks connected with the slide *o*, which is therefore moved right and left by the alternate fall of the floats.

H is the trough or reservoir, into which the water flows from the discharging valves,

* This drawing, as well as the description, has been seen and minutely examined by the Patentee.

and from whence it passes on the overshot wheel.

To effect the vacuum, the requisite quantity of gas is admitted along the pipe *kk* into the burners, and also along the pipe *t*, at the ends of which it must be lighted. Then draw down the end *a* of the beam, when the cover *c* will fall and close the top of the cylinder A; the fall also of the rod *m* and the arm *v* will likewise push down the slide valve *s*, and close the orifice, making the cylinder air-tight. The flame from the pipe *t*, having issued through the orifice while open and ignited, the gas issuing from the burner and jet, a vacuum will be instantaneously effected by the combustion of the gas, and the water as rapidly raised from the vessel E by the pressure of the atmosphere on its surface, lifting the clack *i* by its force upwards, and rushing along the pipe F, and the passage way into the inner cylinder over its top. The fall of the float L, will now by the chain *l*, pull the crank and draw along the slide *o*, and thus admit the air into the cylinder. The water (closing by its gravity the clack at *i*) will then be discharged through the pipe C and its valve into the trough H, from whence it flows on the overshot wheel, and from thence along the case *e* into the receiver *f*. The cylinder D being full of water, the float K pushing up the rod *m*, now lifts the end *a* of the beam—the end *b* and the cover *d* consequently fall—the gas has been admitted into the cylinder B and ignited—the orifice is closed, and a vacuum is effected in that cylinder in the same manner as it was in the other. The water will now be discharged as before, and the rotatory motion of the water-wheel be continued. The rise and fall of the rod *n* carrying up and down the arms *r*, which strike against a pin in the tube, raise and lower that end of the tube *h*, and allow the mercury to run alternately from one end to the other, by the action of which the gas cocks are opened and shut, and the slide *y* moved backwards and forwards over the entrances to the pipes *g* and *g*, to allow the water to flow alternately into the vessels D and E, and thus the engine continues to work—the action being on both sides exactly the same.

When water is intended to be raised from any place and discharged, the wheel is taken away, and a pipe or passage way is brought into communication between the place and the reservoir *f*, which is placed just above the level of the water to be raised.

When pistons are worked, the vacuum is produced in the same manner, under the piston which is forced down by the pressure of the atmosphere, when the operation is repeated in another cylinder, so that one or other of the pistons is constantly in motion, and the fly-wheel thereby impelled. In this case the air is admitted through large valves placed in the pistons—or the vacuum may be effected in two cylinders, as it is done in the engine above described, and the piston worked in a separate cylinder, the air being admitted alternately under and over the piston, while the vacuum, being extended by means of a pipe from the other cylinders, acts during the same periods on the opposite side of the piston, by which contrivance any number of strokes per minute may be given as required.

A spectator who views this interesting piece of mechanism is surprised to see its effects, as they are produced without the least noise and in the smoothest manner possible. And it is only by inspecting the mercurial gauge attached to the engine, that one can discover that a vacuum is actually produced. But upon carefully observing the mercury it will be perceived, that it rises to 24 inches, which is equal to a pressure of about 13 lbs. upon every square inch, even in the working model which we have just described, the writer of the present article having seen it rise to this height.

If this is the case at present in the first engine of the kind which has ever been constructed, it is only reasonable to expect that, by experience in their effects and construction, which time and observation can only supply, that the power of the engine may be increased even beyond this extent, which already so far exceeds that of the best condensing steam engines of the present day.

The present model is estimated by the inventor as equal to about a one and a half horse power steam engine. The working cylinders are about eight inches diameter, and the length of the beam about four feet. The whole engine not occupying an area of more than about four feet six inches by two feet. But the frame-work of this engine would be sufficiently strong for an engine of ten times the power; there being neither any lateral pressure, nor strain on the materials; nor vibratory motion from the working of the engine.

To those who consider the wonderful effects of the steam engine, and the revolution it has effected in all the great operations where force is required, the Pneumatic Engine must prove a most interesting object; and should the principle upon which it acts be found to be free from all physical objection, when the engines are constructed upon a larger scale and applied to the purposes to which the steam engine is at present, it is highly probable that *gas* engines will, in many cases, be preferred to *steam* engines.

As hydrogen gas forms a constituent part of water, from which it may be obtained very easily, the means of producing power, in machines upon this principle, can never be wanting if a cheap and convenient apparatus can be obtained for decomposing water, which we doubt not will soon be supplied, as we consider no great effort of *genius* necessary for effecting this.

The power of the pneumatic engine, as we have already remarked, may be increased to any extent by enlarging the dimensions of the cylinder; and may always be ascertained by the mercurial gage attached to the engine, as already noticed.—The *mechanical* parts of such engines will doubtless be continually varied, and this is amply provided for in the specification, but the *combination by which the vacuum is effected* and for which the patent is obtained, must always form the *moving power*, and can only be varied in the form of its construction or arrangement.

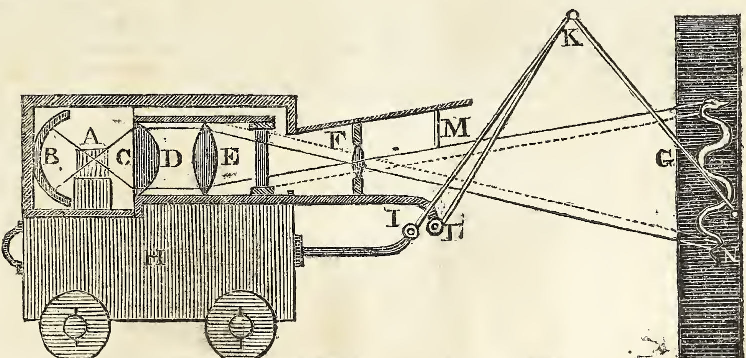
After the description which we have here given of this singular engine, we shall only add, that we are glad to find that the Patentee has secured a patent both in America and in France, as well as in this country.

OPTICS.

ON THE PHANTASMAGORIA.

The term *phantasmagoria*, signifies the raising of spectres, and has been given to an optical apparatus similar to the magic lantern.

The following figure represents an arrangement, which has been proposed by Dr. Young for exhibiting objects according to the plan of phantasmagoria.



The light of the lamp A is thrown by the mirror B, and the lenses C and D, on the painted slider at E, and the magnifier F forms the image on the screen at G. This lens is fixed to a slider, which may be drawn out of the general support or box H, and when the box is drawn back on its wheels, the rod I K lowers the point K, and by means of the rod K L adjusts the slider in such a manner, that the image is always distinctly painted on the screen G. When the box advances towards the screen, in order that the images may be diminished and appear to vanish, the support of the lens F suffers the screen M to fall, and intercept a part of the light. The rod K N must be equal to I K, and the point I must be twice the focal length of the lens F before the object, L being immediately under the focus of the lens: the screen M may have a triangular opening, so as to uncover the middle of the lens only, or the light may be intercepted in any other manner.

In order to favour the deception, the sliders are made perfectly opaque, except where the figures are introduced, the glass being covered in the light parts with a more or less transparent tint, according to the effect required. Several pieces of glass may also be occasionally placed behind each other, and may be made capable of such motions as will nearly imitate the natural motions of the objects which they represent.

The figures may also be drawn with water colours on thin paper, and afterwards varnished. By removing the lantern to different distances, and altering at the same time, more or less, the position of the lens, the image may be made to increase or diminish, and to become more or less distinct at pleasure, so that, to a person unaccustomed to the effects of optical instruments, the figures will appear actually to advance and retire. In reality, however, these figures become much brighter as they are rendered smaller, while in nature the imperfect transparency of the air causes them to appear fainter when they are remote than when they are near. This imperfection might be easily remedied by the interposition of some semi-opaque substance, which might gradually be caused to admit more light, as the figure became larger, or by uncovering a larger or a smaller portion of the lamp or of its lens. Sometimes, by throwing a strong light upon an actual opaque object, or on a living person, its image is formed on the curtain, retaining its natural motions; but in this case the object must be considerably distant, otherwise the images of its nearer and remoter parts will never be sufficiently distinct at once, the refraction being either too great for the remoter, or too small for the nearer parts; and there must also be a second lens placed at a sufficient distance from the first, to allow an inverted image to be formed between them, and to throw a second picture of this image on the screen in its natural erect position, unless the object be of such a nature, that it can be inverted without inconvenience. This effect was very well exhibited at Paris, by Robertson; he also combined with his pictures the shadows of living objects, which imitate tolerably well the appearance of such objects in a dark night, or by moon-shine; and while the room was in complete darkness, concealed screens were probably let down in various parts of it, on which some of the images were projected; for they were sometimes actually situated over the heads of the audience.

CAMERA LUCIDA.

The Camera Lucida is an ingenious and simple instrument lately invented by Dr. Wollaston for drawing objects in perspective; and for copying, reducing, or enlarging other drawings.

It consists of a small prism, supported on a stem, or rod of brass, which turns upon a pin, and may be placed in any position required. The eye is then to be directed through a hole, to the prism; any object may then be delineated which is placed before it for that purpose.

This instrument is represented by the following figures.

Fig.2.

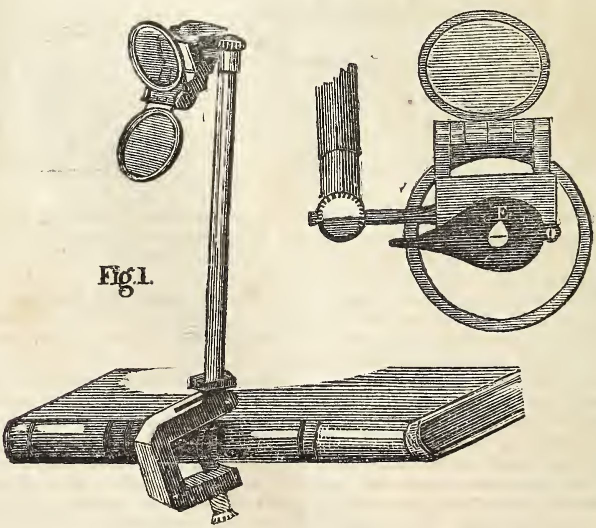


Fig.1.

The instrument being fixed by the screw and clamp to the table and paper on which the drawing is to be made, its stem should be inclined so as to bring the prism nearly over the centre of the paper, and the pin, on which the prism turns, placed truly horizontal.

The instrument, as represented in the figures, may be used either with the small round glass turned up in front, figure 1, or with the larger glass turned up level underneath the instrument, figure 2. *(Seen from above.)* But those who are short-sighted can only use the former, and persons that are long-sighted must use the latter.

The prism is next to be turned upon its pin, till the transparent rectangular face be placed opposite to the objects to be delineated, when the upper black surface of the eye-piece (E, figure 2) will be on the top of the instrument; and through the aperture in this, the artist is to look perpendicularly downwards at his paper.

The black eye-piece E, is moveable, and in ordinary circumstances is to be in such a position, that the edge of the small transparent part at the back of the prism shall intercept about half the eye-hole. The artist then, looking through the eye-hole directly downwards at his paper, should see the objects he wishes to draw, apparently distributed over the paper. For, since his eye is larger than the eye-hole, he sees through both halves of the hole at the same time, without moving his head. He sees the paper through the nearer half, and sees the objects at the same time through the farther half, apparently in the same direction, by means of reflection, through the prism.

The position of the eye-hole, is the circumstance, above all others, necessary to be attended to in adjusting the Camera Lucida for use; for on the due position of this hole depends the possibility of seeing both the pencil and the objects distinctly at the same time.

If the eye-hole be moved, so that nearly the whole of its aperture be over the paper, and a very small portion over the prism, then the pencil and paper will be very distinctly seen; but the objects to be delineated, very dimly. If, on the other hand, the aperture be mostly over the prism, and but a small portion over the paper, then the objects will be seen distinctly, but the pencil and paper will be very faint. But there will always be an intermediate position (varying according as the objects or the paper happen to be most illuminated) in which both will be sufficiently visible for the purpose of delineation, though not quite so clear as to the naked eye. This intermediate position is easily found, with a little practice.

If objects can be seen distinctly on the upper part of the paper, but not upon the lower, the instrument requires to be turned upon its pin, so that the transparent face may be inclined rather downwards, and the contrary for seeing the upper part of the view.

Many persons, upon first attempting to use this instrument, occasionally lose sight of their object or their pencil, merely by means of a little motion of their head, backwards and forwards, of which they are not aware, in breathing; but a very little practice soon obviates this difficulty.

Those who cannot sketch comfortably, without perfect distinctness of both the pencil and object, must draw out the stem to the mark D, for all distant objects, and to the numbers 2, 3, 4, 5, &c. for objects that are at the distances of only 2, 3, 4, or 5 feet respectively, the stem being duly inclined according to a mark placed at the bottom; but after a very little practice, such exactness is wholly unnecessary.

The farther the prism is removed from the paper, that is, the longer the stem is drawn out, the larger the objects will be represented in the drawing, and, accordingly, the less extensive the view.

In copying drawings, the copy will be larger or smaller than the original, according as the prism is more or less distant from the paper than it is from the drawing to be copied. Thus, if the drawing be two feet from the prism, and the paper only one foot, the copy will be half the size of the original. If the drawing be at one foot, and the paper three feet distant, the copy will be three times as large as the original; and so for all other distances.

Some caution is requisite in placing the instrument directly before the drawing to be copied, otherwise it will become distorted by a new perspective.

In copying a landscape, the eye-hole should be drawn so far off the prism as to leave the reflected images barely distinct, for the more complete command of the pencil, which is intended to be brought into coincidence with the images, and to be employed in rendering their outlines permanent.

OF THE TELESCOPE.

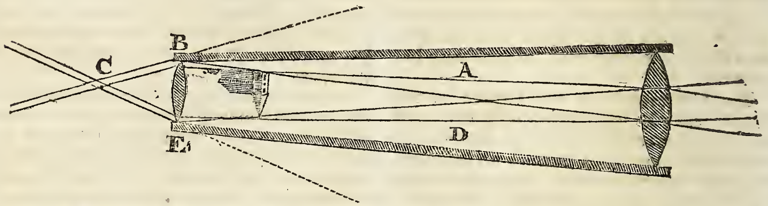
The Telescope is an instrument employed for viewing distant objects, and is, perhaps, one of the most valuable and remarkable instruments that has ever been constructed for gratifying our curiosity and extending our knowledge.

Telescopes may be divided into two kinds, Refracting and Reflecting; these we shall describe in their order.

Refracting telescopes are of two kinds, Astronomical and Terrestrial.

ASTRONOMICAL TELESCOPE.

The Astronomical Telescope which was invented by Kepler is represented by the following figure.



It consists of two convex glasses placed in a tube; the one next the object is called the object-glass, and the one next the eye, as B E, the eye-glass, which is always of a much less focal length than the object-glass. The focal length of the object-glass is a little greater than the tube into which it is screwed, and the eye-glass is fixed into a small tube, which can be moved out and in at the other extremity of the longer tube. When such an instrument is directed to a distant object, and distinct vision obtained by adjusting the tube containing the eye-glass, the magnified object is formed by the rays A B C and D E C, which come from the extremities of the visible field through the middle of the object-glass, and produce an inverted image nearly in the principal focus of the eye-glass, through which this image is viewed as by a simple microscope, and therefore still remains apparently inverted. This, however, is not considered a disadvantage by astronomers, and therefore it has received the name of the *astronomical telescope.*

In order to find the magnifying power, we must divide the focal length of the object-glass by that of the eye-glass: this quotient is consequently the greater as the focal length of the object-glass is greater, and as that of the eye-glass is smaller; but the power of the instrument cannot be increased at pleasure by lessening the focal length of the eye-glass, because the object-glass would not furnish light enough to render the view distinct, if the magnifying power were too great.

GALILEAN TELESCOPE.

The Galilean Telescope received its name from its having been first used by Galileo, and differs in no respect from the astronomical telescope, excepting in the substitution of a concave eye-glass in place of a convex eye-glass. This eye-glass is placed between the object-glass and its principal focus, and receives the converging rays before they form the image.

The magnifying power of this telescope will be equal to the focal length of the object-glass divided by that of the eye-glass; for the extreme pencils which were formerly made to converge, are now made to diverge.

This telescope possesses some advantages over the astronomical telescope. 1st. It has the same magnifying power under a shorter length, the length of the telescope being equal to the difference of the focal lengths of the object-glass and the eye-glass, whereas in the astronomical telescope it is equal to their sum. 2d. It gives us an erect view of the object without using three eye-glasses, which must occasion a great loss of light, even if the lenses are ground to a perfect figure. 3d. There is less absorption of light, in consequence of the rays passing through a less thickness of eye-glass; and 4th. the vision is much more perfect; a circumstance which no doubt arises from the rays never coming to a positive focus, and never crossing one another in a condensed state during the whole of their progress through the instrument. For it cannot be doubted that the rays of light, notwithstanding their extreme tenuity, interfere with one another, and produce an indistinctness of vision.

The disadvantages of the Galilean telescope arise solely from its limited field of view. Since the lateral pencils now diverge from the axis of the lenses, the field of view depends solely on the diameter of the pupil of the eye, and as this cannot be increased at pleasure, there are no means of remedying this evil in the Galilean telescope.

The imperfections of the common refracting telescope with a single object-glass, are so great, that in order to obtain a high magnifying power, it is necessary to use object-glasses of a great focal length, such as those of Huygens, some of which were not less than 24 feet in length*.

It follows from the theory of aberration, arising from the spherical figure of the surface, that the apparent indistinctness of a given object seen through a refracting telescope, is directly as the area of the object-glass, and inversely as the square of the focal distance of the eye-

* This excellent astronomer while in England presented the Royal Society with two object-glasses, one of which had a focal length of 120, and the other of 123 feet.

glass. In like manner, it may be shown, that the apparent brightness of a given object is directly as the square of the lineal aperture of the object-glass, and inversely as the square of its magnifying power. Hence, it follows, that in refracting telescopes of different lengths, a given object will appear equally bright, and equally distinct, when their linear apertures, and the focal distances of the eye-glasses, are as the square roots of the focal distances of their object-glasses, and consequently their magnifying powers will be as the square roots of the focal distances of the object-glasses.

Upon these principles, we may compute the focal distance of the eye-glasses suited to object-glasses of different focal lengths, provided we have once ascertained by experiment the highest magnifying power that an object-glass of a given focal length will bear with perfect distinctness. One of Huygen's best telescopes, 30 feet long, had an aperture of three inches, with an eye-glass three inches and $\frac{3}{10}$ in focal length, and from this telescope, as a standard, the editors of his Dioptrics computed the table given in p. 211 of that work, and reprinted by Dr. Smith in the 148th page of the first volume of his Optics. It appears, however, from Astroscopia Compendiaria of Huygens, that he possessed a telescope superior even to this, whose object-glass was 34 feet in focal length, and which had a magnifying power of 163 times, with an eye-glass of $2\frac{1}{2}$ inches focal length.

In order to render the common refracting telescope as perfect as possible, without making it achromatic, the spherical aberration should be reduced by grinding the exterior surface of the object-glass to a radius equal to *five-ninths* of its focal length, and the interior surface to a radius equal to *five times* its focal length. In the eye-glasses, the radius of the surface next the object should be *nine* times its focal length, and that of the surface next the eye, three-fifths of the same distance.

When the object to which the telescope is directed is luminous, such as the Sun, and Jupiter, and Venus, when they are near the earth, considerable advantage may be derived from the use of red or green eye-glasses, or, if the telescope is large, from the interposition of plane pieces of green and red glass.*

* Pieces of plane glass, when smoked in the flame of a lamp, serve the same purpose.

CHEMISTRY.

CHLORINE.

The introduction of the term *Chlorine* marks an important era in the science of chemistry. It originated with Sir H. Davy, about the year 1811. At that time he was engaged in making some experiments on oxymuriatic acid gas*, which after resisting the most powerful means of decomposition which he could employ, he declared to be an elementary body, or simple substance; and not a compound of muriatic acid and oxygen as was previously imagined, and as its name indicated. He accordingly gave it the name of Chlorine, a term merely descriptive of its colour, which is that of a greenish-yellow.

Without venturing to give any opinion respecting the propriety of this name, or the composition of the body, we may remark, that it cannot be in conformity with the rules of a strict and accurate nomenclature to call a body by a name, which indicates properties it does not possess.

Chlorine, or chloric gas, may be obtained as follows:

Mix *three* parts of common salt with *one* of black oxide of manganise. Introduce this mixture into a glass retort, and add *two* parts of sulphuric acid. Gas will then issue from the retort in considerable quantity, which may be collected in jars over water in the usual way. The production of the gas will be favoured by the application of a gentle heat. As part of the consistance formed by the ingredients used in this process is apt to boil over into the neck of the retort, a mixture of liquid muriatic acid and manganise is more convenient for producing chlorine. When this process is employed, a very slight degree of heat is sufficient to extricate the gas. The red oxide of lead, or mercury, may be employed instead of manganise.

This gas, as already remarked, is of a greenish-yellow colour, which is quite perceptible by day-light; but scarcely discernible by candle-light.

Its odour and taste are disagreeable, strong, and so characteristic, that it is impossible to mistake it for any other gas.

When it is breathed, even much diluted with atmospherical air, it occasions a sense of strangulation, constriction of the *thorax*, and a copious discharge from the nostrils. If respired in larger quantity, it excites violent coughing, with spitting of blood, and would speedily occasion the death of the individual in great distress.

* This gas was discovered by Scheele, and called by him dephlogisticated muriatic acid; but was afterwards called oxymuriatic acid, by the French chemists.

Its specific gravity is 2·473. This is better inferred from the specific gravities of hydrogen and muriatic acid gas, than from its direct weight, on account of the impossibility of confining it over mercury.

One volume, or measure of hydrogen, added to one of chlorine, form two of the acid gas. Hence, if from twice the specific gravity of muriatic gas, which is 2·543, we subtract that of hydrogen, which is 0·069, the difference, or 2·474, is the specific gravity of chlorine. At a mean temperature and pressure, 100 cubic inches weigh $75\frac{1}{2}$ grains.

In its perfectly dry state it has no effect on dry vegetable colours; but with the aid of a little moisture it bleaches or turns them of a yellowish-white colour.

Scheele who discovered this gas, was also the first who discovered its bleaching property. Berthollet applied it to the art of bleaching in France, from whom the late Mr. Watt learned the process, while in Paris, and introduced it into this country, where it is now employed to a very great extent in bleaching both linen and cotton.

If a lighted taper be immersed rapidly into this gas, it consumes very fast, burning with a dull reddish flame, and giving out much smoke. The taper will not burn at the surface of the gas. Hence if it be slowly introduced, it is apt to be extinguished.

Potassium, sodium, copper, tin, arsenic, zinc, antimony, and several other metals, take fire and burn spontaneously in this gas if introduced in fine laminæ, or filings.

Phosphorus also takes fire at ordinary temperatures.

The result of the combustion of any substances in chlorine is termed a chloride, as chloride of zinc, chloride of phosphorus, &c. Sulphur may be melted in chlorine without taking fire, and in this state it forms a liquid chloride, of a reddish colour. When dry, it is not altered by any change of temperature; but when enclosed in a phial with a little moisture, it concretes into crystalline needles, at 40° of Fahrenheit's scale.

According to M. Thenard water condenses $1\frac{1}{2}$ times its bulk of chlorine, at the temperature of 68° F. and 29·92 Barom., and forms aqueous chlorine, or what was formerly called liquid oxymuriatic acid. This combination is best effected in the second bottle of a Woolfe's apparatus: see the figure in page 232, the first bottle being charged with a little water to intercept the muriatic acid gas, while the third bottle may contain a solution of potash in water or milk of lime, to condense the superfluous gas. M. Thenard says, that a kilogramme, or about $2\frac{1}{3}$ pounds avoirdupoise of salt, is sufficient to saturate 10 litres, or about 21 English pints of water. Mr. Tennent, of Glasgow has superseded the necessity of saturating water with this gas for the purpose of bleaching, by substituting slaked lime for water.

This liquid chloride of lime congeals at a temperature of 40° of Fahrenheit, and affords crystallized plates of a deep yellow colour, containing a less portion of water than the liquid combination. Hence, when chlorine is passed into water at a temperature under 40° the liquid finally becomes a concrete mass, which a gentle heat liquifies with effervescence from the escape of the excess of chlorine.

It is in the liquid state that it is employed in bleaching, and when used in this way it is always decomposed: for the liquor after it has been employed in bleaching will be found to have lost its smell; and to precipitate nitrate of mercury, which it will not do before, if it be pure. In fact, this is the best test for determining whether it be pure or not. It often contains a portion of muriatic acid, and when this is the case, it has the effect of precipitating mercury from its solution in nitric acid, which it does not do when perfectly free from muriatic acid.

The watery solution is also decomposed when exposed to the direct rays of the sun; therefore when it is intended for bleaching, it ought to be kept from the direct rays of the sun.

It has already been remarked, that slaked lime saturated with chlorine has been employed in bleaching as well as the watery solution of it; but we ought to add, that it is found to answer much better for this purpose than the watery solution, and is less dangerous both to the goods and the constitutions of those who are employed in using it for this purpose.

When the gas is passed into a trough containing slacked calcined lime in the state of a paste, it combines with the lime and converts it into a dry powder; which when mixed with water has also the power of discharging colour, and is therefore now much employed in the bleaching of goods. Magnesia is also employed in the same way in bleaching the finer kinds of muslin.

When steam and chlorine are passed together through a red-hot porcelain tube, they are converted into muriatic acid and oxygen. Aqueous chlorine attacks almost all the metals at an ordinary temperature, forming muriates or chlorides, and heat is evolved. It has the smell, taste, and colour of chlorine; its taste is somewhat astringent, but not in the least degree acidulous.

When we put in a perfectly dark place, at the ordinary temperature, a mixture of chlorine and hydrogen, it experiences no kind of alteration, even in the space of a great many days. But, if at the same low temperature, we expose the mixture to the diffuse light of day, by degrees the two gases enter into chemical combination, and form muriatic acid gas. There is no change in the *volume* of the mixture, but the change of its *nature* may be proved, by its rapid absorption by water, its not exploding by the lighted taper, and the disappearance of the chlorine hue. To produce the complete discoloration, we must expose the mixture finally for a few minutes to the sun-beam. If exposed at first to this intensity of light, it explodes with great violence, and instantly forms muriatic acid gas. The same explosive combination is produced by the electric spark and the lighted taper. M. Thenard says, a heat of 392° is sufficient to cause the explosion. The proper proportion is an equal volume of each gas. Chlorine and nitrogen combine into a remarkable detonating compound, by exposing the former gas to a solution of an ammoniacal salt. (See Nitrogen.)

Chlorine is now much employed in purifying places of noxious vapours, as it soon neutralizes every species of noxious effluvia. It is also said to have the effect of recovering putrid animal matter.

If diluted muriatic acid be added to chlorate of potash, (potash combined with chlorine) another gas will be produced.

It is of a deeper yellow colour than chlorine, and has also the effect of discharging vegetable colours; but it first gives blue colours a tint of red. When a vessel of this gas is exposed to a moderate heat, it explodes and is decomposed into a mixture of chlorine and oxygen gas.

Thus gas was discovered by Sir H. Davy in 1811, and called by him *Euchlorine.*

It has the effect of inflaming sulphuric ether, alcohol, and oil of turpentine when poured into it.

As we have now described the chief properties of chlorine, and mentioned some of the uses to which it is now successively applied in the arts; it may not be improper to add a short account of the experiments made upon it by Sir H. Davy; and the reasoning he has employed to prove that it is a simple or elementary body.

He subjected oxymuriatic gas to the action of many simple combustibles, as well as metals, and from the compounds formed, endeavoured to eliminate oxygen, by the most enegetic powers of affinity and voltaic electricity, but without success, as the following abstract will shew:

He admitted the ammoniacal gas over Mercury to a small quantity of the liquor of Libavius; it was absorbed with great heat, and no gas was generated; a solid result was obtained, which was of a dull white colour: some of it was heated, to ascertain if it contained oxide of tin; but the whole volatilized, producing dense pungent fumes.

Another experiment of the same made with great care, and in which ammonia was used in great excess, proved that the liquor of Libavius cannot be decompounded by ammonia; but that it forms a new combination with this substance.

He made a considerable quantity of the solid compound of oxymuriatic acid and phosphorus by combustion, and saturated it with ammonia, by heating it in a proper receiver fitted with ammoniacal gas, on which it acted with great energy, producing much heat: and they formed a white opaque powder. Supposing that this substance was composed of the dry muriates and phosphates of ammonia; as muriate of ammonia is very volatile, and as ammonia is driven off from phosphoric acid, by a heat below redness, he conceived that, by igniting the product obtained, he should procure phosphoric acid; he therefore introduced some of the powder into a tube of green glass, and heated it to redness, out of the contact of air, by a spirit lamp; but found, to his great surprise, that it was not at all volatile nor decomposable at this degree of heat, and that it gave off no gaseous matter.

The circumstance, that a substance composed principally of oxymuriatic acid and ammonia, should resist decomposition or change at so high a temperature, induced him to pay particular attention to the properties of this new body.

He mixed together sulphuretted hydrogen in a high degree of purity, and oxymuriatic acid gas, both dried in equal volumes. In this instance the condensation was not $\frac{1}{40}$; sulphur, which seemed to contain a little oxymuriatic acid, was formed on the sides of the vessel; no vapour was deposited; and the residual gas contained about $\frac{19}{20}$ of muriatic acid gas, and the remainder was inflammable.

He caused strong explosions from an electrical jar to pass through oxymuriatic gas, by means of points of platina, for several hours in succession; but it seemed not to undergo the slightest change.

He electrized the oxymuriates of phosphorus and sulphur for some hours, by the power of the voltaic apparatus of 1000 double plates. No gas separated, but a minute quantity of hydrogen, which he was inclined to attribute to the presence of moisture in the apparatus employed; for he once obtained hydrogen from Libavius's liquor by a similar operation. But he ascertained that this was owing to the decomposition of water adhering to the mercury; and in some late experiments made with 2000 double plates, in which the discharge was from platina wires, and in which the mercury used for confining the liquor was carefully boiled, there was no production of any permanent elastic matter.

ASTRONOMY

SPOTS, MOUNTAINS, &c. IN THE MOON.

Turn'd to the sun direct, her spotted disk
Shows mountains rise, umbrageous dales descend,
And caverns deep, as optic tube descries.

THOMSON.

When the moon is viewed through a good Telescope, her surface appears to be diversified with hills and valleys; but this is most discernable when she is observed a few nights after the Change or Opposition, for when she is either *horned* or *gibbous*, the edge about the confines of the illuminated part is jagged and uneven.

Many celebrated Astronomers have delineated maps of the face of the moon; but the most celebrated are those of Hevelius, Grimaldi, Riccioli, and Cassini; in which the appearance of the moon is represented in its different states, from *new to full, and from full to new*.

The plate which we have given at page 203, represents the face of the moon as viewed by the most powerful telescopes, the light or illuminated parts being elevated tracts, some of which rise into very high mountains, while the dark parts appear to be perfectly smooth and level. This apparent smoothness in the faint parts, naturally led Astronomers to conclude that they were immense collections of water; and the names given to them, by some celebrated Astronomers, are founded on this supposition. For Hevelius distinguished them by giving them the names of the seas on the earth; while he distinguished the bright parts by the names of the countries and islands on the earth. But Riccioli and Langreni distinguished both the dark and light spots, by giving them the names of celebrated Astronomers and Mathematicians, which is now the general manner of distinguishing them.

That the spots which are taken for mountains and valleys are really such, is evident from their *shadows*. For in all situations in which the moon is seen from the earth, the elevated parts are constantly found to cast a triangular shadow in a direction from the sun; and on the contrary, the cavities are always dark on the side next the sun, and illuminated on the opposite side, which is quite conformable to what we observe of hills and valleys on the earth. And as the tops of these mountains are considerably elevated, above the other parts of the surface, they are often illuminated when they are at a considerable distance from the line which separates the enlightened from the unenlightened part of the disc, and by this means afford us a method of even determining their height.

Previous to the time of Dr. Herchel, some of the lunar mountains were considered to be double the height of any on the earth; but by the observations of that celebrated Astronomer, their height is considerably reduced.

For after measuring many of the most conspicuous prominences, he says, "From these observations I believe it is evident, that the height of the lunar mountains is, in general, overrated; and that when we have excepted a few, the generality do not exceed half a mile in their perpendicular elevation."

As the moon's surface is diversified by mountains and valleys as well as the earth, some modern Astronomers say they have discovered a still greater similarity; namely, that some of these are really volcanoes, emitting fire, as those on the earth do. An appearance of this kind was discovered by Don Ulloa in an eclipse of the sun, which happened on the 24th June, 1778. It was a small bright spot like a star near the margin of the moon, which he supposed at the time to be a hole or valley, which permitted the sun's light to shine through it. Succeeding observations have, however, led Astronomers to believe, that appearances of this kind are occasioned by the eruption of volcanic fire. Dr. Herschel, in particular, has observed several eruptions of this kind, the last of which he has described in the Philosophical Transactions for 1787, as follows: "On April the 19th, at 10h. 6 m. I perceived three volcanoes in different places of the dark part of the new moon. Two of them are either already nearly extinct, or otherwise in a state of going to break out, which perhaps may be decided next lunation. The third shows an actual eruption of fire or luminous matter: its light is much brighter than the nucleus of the comet which M. Mechain discovered at Paris on the 10th of this month." The following night the Doctor found it burned with greater violence; and by measurement he found that the shining or burning matter must be more than three miles in diameter, of an irregular round figure, and very sharply defined about the edges. The other two volcanoes resembled large faint nebulæ, which appeared to be gradually brighter towards the middle, but no well defined luminous spot could be discovered in them. Dr. Herschel adds, "the appearance of what I have called the actual fire, or eruption of a volcano, exactly resembled a small piece of burning charcoal, when it is covered by a very thin coat of white ashes, which frequently adhere to it when it has been some time ignited; and it had a degree of brightness about as strong as that with which a coal would be seen to glow in fair day light."

The appearance which Dr. Herschel here describes so minutely, was also observed at the Royal Observatory of Paris, about six days before, by Dominic Nouet, like a star of the sixth magnitude, the brightness of which occasionally increased by flashes. Other Astronomers also saw the same thing, for M. de Villeneuve observed it on the 22d of May, 1787. This volcano is situated in the north-east part of the moon, about 3′ from her edge, towards the spot called Helicon. After considering all the circumstances respecting these appearances which have just been mentioned, we must subscribe to Dr. Herschel's opinion, that volcanoes exist in the moon as well as the earth.

It has long been a disputed point among Astronomers, whether or not the moon is surrounded by an atmosphere. Those who deny that she is, say that the moon always appears with the same brightness when our atmosphere is clear; which could not be the case if she were surrounded by an atmosphere like ours, so variable in density, and so often obscured by clouds and vapours.

A second argument is, that when the moon approaches a star, before she passes between it and the earth, the star neither alters its colour nor its situation, which would be the case if the moon had an atmosphere, on account of the refraction which would both alter the colour of the star, and also make it appear to change its place.

A third argument is, that as there are no seas or lakes in the moon, there is, therefore, no atmosphere, as there is no water to be raised up into vapour. But those who contend that the moon is surrounded by an atmosphere, deny that she always appears of the same brightness, even when our atmosphere appears equally clear. Instances of the contrary are mentioned by Hevelius and some other Astronomers, but it is unnecessary to take any farther notice of them here. In the case of total eclipses of the moon, it is well known that she exhibits very different appearances, which it is supposed are owing to changes in the state of her atmosphere. It is remarked by Dr. Long, that Newton has shown that the weight of any body on the moon, is but a third part of the weight of what the same body would be on the earth, from which he concludes that the atmosphere of the moon is only one third part as dense as that of the earth, and therefore it is impossible to produce any sensible refraction on the light of a fixed star which may pass through it. Other Astronomers assert that they have observed such a refraction; and that Jupiter, Saturn, and the fixed stars had their circular figures changed into an elliptical one, on these occasions. But although the moon be surrounded by an atmosphere of the same nature as that which surrounds the earth, and to extend as far from her surface; yet no such effect as a gradual diminution of the light of a fixed star could be occasioned by it, at least none, that could be observed by a spectator on the earth. For at the height of 44 miles our atmosphere is so rare, that it is incapable of refracting the rays of light, now this height is only the 180th part of the earth's diameter; but as clouds are never observed higher than 4 miles, it therefore follows that the obscure part of our atmosphere is about the 2000th part of the earth's diameter, and if the moon's apparent diameter be divided by this number, it will give the angle under which the obscure part of her atmosphere will be seen from the earth, which is not quite one second, a space passed over by the moon in less than two seconds of time. It can, therefore, scarcely be expected that any obscuration of a star could be observed in so short a time, although it do take place.

As to the argument against a lunar atmosphere drawn from the conclusion, that there are no seas or lakes in the moon, it proves nothing, because it is not positively known whether there is any *water* in the moon or not.

The question of a lunar atmosphere seems to be at last settled by the numerous and accurate observations of the celebrated Astronomers Shroeter and Piazzi, who have proved as convincingly as the nature of the subject seems to allow, that the moon has really an atmosphere, though much less dense than ours, and scarcely exceeding in height some of the lunar mountains.

It is remarked by Dr. Brewster, "The mountain scenery of the moon bears a stronger resemblance to the lowering sublimity and terrific ruggedness of the Alpin regions, than to the tamer inequalities of less elevated countries. Huge masses of rock rise at once from the plains, and raise their peaked summits to an immense height in the air, while projecting craggs spring from their rugged flanks, and threatening the valleys below seem to bid defiance to the laws of gravitation. Around the base of these frightful eminences, are strewed numerous loose and unconnected fragments, which time seems to have detached from their parent mass, and when we examine the rents and ravines which accompany the overhanging cliffs, we expect every moment that they are to be torn from their base, and that the process of destructive separation which we had only contemplated in its effects, is about to be exhibited before us in tremendous reality. The mountains called the Appennines, which traverse a portion of the moon's disc from north-east to south-west, rise with a precipitous and craggy front from the level of the *Mare* Imbrum. In some places their perpendicular elevation is above four miles; and though they often descend to a much lower level, they present an inaccessible barrier to the north-east, while on the south-west they sink in gentle declivity to the plains."

The caverns which are observed on the moon's surface, are no less remarkable than the rocks and mountains, some of them being three or four miles deep, and forty in diameter. A high angular ridge of rocks marked with lofty peaks and little cavities, generally encircles them, an insulated mountain frequently rises in their centre, and sometimes they contain smaller cavities of the same nature with themselves. These hollows are most numerous in the south-west part of the moon, and it is from this cause that this part of the moon is more brilliant than any other part of her disc. The mountainous ridges which encircle the cavities, reflect the greatest quantity of light; and from their lying in every possible direction, they appear, near the time of full moon, like a number of brilliant radiations issuing from the small spot called Tycho.

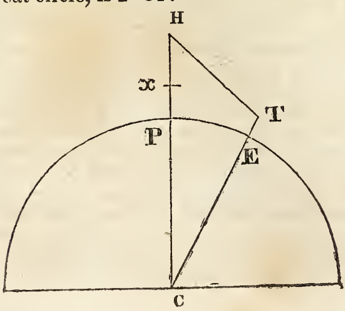
It is difficult to explain, with any degree of probability, the formation of these immense cavities; it is highly probable that the earth would assume the same figure, if all the seas and lakes were removed; and that the lunar cavities are either intended for the reception of water, or that they are the beds of lakes and seas which have formerly existed in the moon.

The circumstance of there being no water in the moon, affords a strong proof of the truth of this theory."

SOLUTIONS OF QUESTIONS.

QUEST. 36, *answered by* Mr. S. A. HART, Artist.

The distance between St. Paul's and the Eddystone Light-house, on the arc of a great circle, is $2^\circ\ 54'$.



Then let P denote the base of St. Paul's Px the height of the cross 344 feet, C denote the centre of the earth, E the Eddystone, ET the height of the Eddystone 100 feet, $PE = 2^\circ\ 54'$, and xH the height above the cross, which the observer must be elevated, and let $CE + ET = CT = 3978$ miles.

Then by Trigonometry. As Cosine $\angle C = \cos. 2^\circ 54' : CT = 3978 :: \text{rad. } 90^\circ : CI = 3983'$. Then CI minus $CP = PH =$ 3983 miles—3978,875 = 4·125 miles = 4 miles 660 feet. Lastly, PH minus $Px = x\,I = 4$ miles 660 feet minus 344 feet = 4 miles 316 feet above the cross, the observer must be elevated to see the top of the Eddystone required.

This question was also answered by Mr. J. WHITCOMB exactly in the same manner.

The answer would have been closer had CT been reduced to feet, and the difference between English and Geographical miles attended to.—ED.

QUEST. 37, *answered by* Mr. J. TAYLOR, *Clement's-lane, Lombard-street.*

Add the square of half the chord of the arc, to the square of the versed sine, and divide the sum by the versed sine, which will quote the diameter of the circle, the square of which, multiplied by ·7854, will be the area of the circle.

This question was also correctly answered by Messrs. HUGH STARKE; J. HOLROYD, *Oldham;* JOHN BARR; and the Proposer; but we prefer the above, because no figure is wanted.—ED.

QUESTIONS FOR SOLUTION.

QUEST. 41, *proposed by* J. TAYLOR.

I have an old clock, whose pendulum vibrates as many times in a minute as it is inches in length; I demand the length of the pendulum and number of vibrations in an hour?

QUEST. 42, *proposed by* A. B. *Walworth.*

Suppose a tube 30 inches long, filled with mercury, except 8 inches, to be inverted in a basin of mercury, at what height will the mercury stand in this tube, when the common barometer is at 28 inches?

ERRATA.

In page 228—line 13—col. 1, *for* 3·2 *read* 7·2.

———————— 17——*dele* ÷ 39·6971.

———————— 24 and 25—col. 2, *for* inches *read* feet.

GEOMETRY.

BOOK II.

DEFINITIONS.

The second Book of Euclid treats wholly of *rectangles* and *squares*, shewing that the squares or rectangles of the parts of a line, divided in a specified manner, are equal to other squares or rectangles of the parts of the same line, divided differently; and also that the square of any side of a triangle exceeds or falls short of the sum of the squares of the other two sides by a constant and known rectangle, or square.

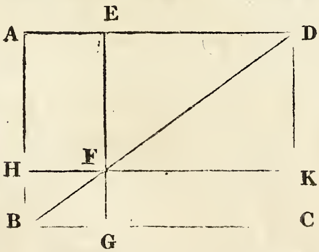
As Rectangles and Squares may be represented by *letters* or *numbers*, as well as by geometrical diagrams, some editors of the Elements prefer the Algebraic mode of demonstrating the propositions in the second book to the Geometrical method.

This we cannot give our sanction to, because it is not only deviating from the mode by which the other books are demonstrated, but it possesses no advantages over that method.

We shall, therefore, continue to employ the geometrical mode of demonstrating *this* book as well as the former; but in order to render the propositions as intelligible and easily understood as possible, we shall illustrate most of them by numbers.*

Every right angled parallelogram is said to be contained by any two of the straight lines which contain one of the right angles.

In every parallelogram, any of the parallelograms about a diameter, together with the two complements, is called a Gnomon. "Thus the parallelogram H G, together with the complements A F, F C, is the gnomon, which is more briefly expressed by the letters A G K, or E H C, which are at the opposite angles of the parallelograms which make the gnomon."



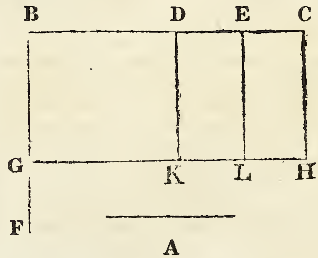
* This is what any person may do who can multiply, divide and extract the square root of numbers; for if the word *number* be inserted instead of *line*, in the enunciation of any theorem where rectangles only are concerned, the truth of the proposition may be established numerically, as well as geometrically.

Every right angled parallelogram is called a *rectangle*.*

PROPOSITION I.

THEOREM.—*If there be two straight lines, one of which is divided into any number of parts; the rectangle contained by the two straight lines is equal to the rectangles contained by the undivided line, and the several parts of the divided line.*

Let A and B C be two straight lines; and let B C be divided into any parts in the points D, E; the rectangle contained by the straight lines A, B C is equal to the rectangle contained by A, B D, together with that contained by A, D E, and that contained by A, E C.



From the point B draw B F at right angles to B C, and make B G equal to A; and through G draw G H parallel to B C; and through D, E, C, draw D K, E L, C H, parallel to B G; then the rectangle B H is equal to the rectangles B K, D L, E H; and B H is contained by A, B C, for it is contained by G B, B C, and G B is equal to A; and B K is contained by A, B D, for it is contained by G B, B D, of which G B is equal to A; and D L is contained by A, D E, because D K, that is B G, is equal to A; and in like manner the rectangle E H is contained by A, E C: therefore the rectangle contained by A, B C, is equal to the several rectangles contained by A, B D, and by A, D E; and also by A, E C. Wherefore, if there be two straight lines, &c. Q. E. D.

This proposition simply amounts to this: any number, or any space included by lines, is equal to the sum of all its parts, therefore it requires no illustration.

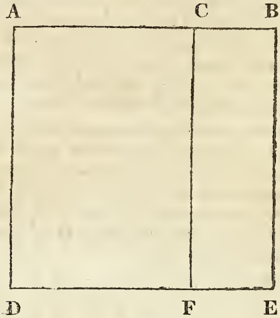
PROPOSITION II.

THEOREM.—*If a straight line be divided into any two parts, the rectangles contained by the whole and each of the parts, are together equal to the square of the whole line.*

Let the straight line AB be divided into

* The word *rectangle* in Geometry, corresponds to that of *product* in Arithmetic.

any two parts in the point C; the rectangle contained by A B, B C, together with the rectangle A B, A C, shall be equal to the square of A B.



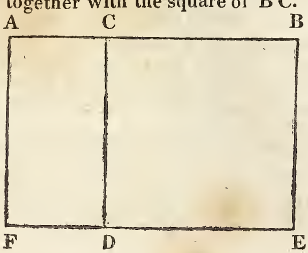
Upon A B describe the square A D E B, and through C draw C F, parallel to A D or B E; then A E is equal to the rectangles A F, C E; and A E is the square of A B; and A F is the rectangle contained by AB, A C; for it is contained by D A, A C, of which A D is equal to A B; and C E is contained by A B, B C, for B E is equal to A B; therefore the rectangle contained by A B, A C together with the rectangle A B, B C, is equal to the square of A B. If therefore a straight line, &c. Q. E. D.

Let the line be represented by the number 8, and let it be divided into the two parts 5 and 3; then the rectangles contained by the whole and each of the parts are, 8 multiplied by 5, or 40; and 8 multiplied by 3 or 24: these together make 64, which is just equal to 8 squared, or multiplied by itself. Hence, the truth of the proposition is established numerically as well as geometrically.

PROPOSITION III.

Theorem.—*If a straight line be divided into any two parts, the rectangle contained by the whole and one of the parts, is equal to the rectangle contained by the two parts, together with the square of the foresaid parts.*

Let the straight line A B be divided into any two parts in the point C; the rectangle A B, B C is equal to the rectangle A C, CB, together with the square of B C.



Upon B C describe the square C D E B, and produce E D to F, and through A draw A F parallel to C D or B E; then the rectangle A E is equal to the rectangles A D, C E; and A E is the rectangle contained by A B, B C, for it is contained by A B, B E, of which B E is equal to B C; and A D is contained by A C, C B, for C D is equal to C B; and D B is the square of B C; therefore the rectangle A B, B C is equal to the rectangle A C, C B, together with the square of B C. If therefore a straight line, &c. Q. E. D.

Let the line be represented by 8, and its parts by 5 and 3, as in last prop. then the rectangle contained by the whole (8) and one of the parts, namely 5, is 40; which is equal to 5 multiplied by 3 or 15, added to the square of 5 or 25.

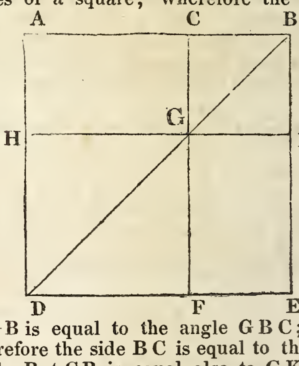
What is meant here by the *foresaid* part is, that part which is employed with the whole to form the rectangle.

PROPOSITION IV.

Theorem.—*If a straight line be divided into any two parts, the square of the whole line is equal to the squares of the two parts, together with twice the rectangle contained by the parts.*

Let the straight line A B be divided into any two parts in C; the square of A B is equal to the squares of A C, C B, and to twice the rectangle contained by A C, C B.

Upon A B describe the square A D E B, and join B D, and through C draw C G F parallel to A D or B E, and through G draw H K parallel to A B or D E: And because C F is parallel to A D, and B D falls upon them, the exterior angle B G C is equal to the interior and opposite angle A D B; but A D B is equal to the angle A B D, because B A is equal to A D, being sides of a square; wherefore the angle



C G B is equal to the angle G B C; and therefore the side B C is equal to the side C G: But C B is equal also to G K, and C G to B K; wherefore the figure C G K B is equilateral: It is likewise rectangular; for C G is parallel to B K, and C B meets them; the angles K B C, G C B are therefore equal to two right angles; and K B C is a right angle; wherefore G C B is a right angle; and therefore also the angles

CGK, GKB opposite to these, are right angles, and CGKB is rectangular: But it is also equilateral, as was demonstrated; wherefore it is a square, and it is upon the side CB: For the same reason HF also is a square, and it is upon the side HG, which is equal to AC: Therefore HF, CK are the squares of AC, CB; and because the complement AG is equal to the complement GE, and that AG is the rectangle contained by AC, CB, for CG is equal to CB; therefore GE is also equal to the rectangle AC, CB; wherefore AG, GE are equal to twice the rectangle AC, CB: And HF, CK are the squares of AC, CB; wherefore the four figures HF, CK, AG, GE are equal to the squares of AC, CB, and to twice the rectangle AC, CB: But HF, CK, AG, GE make up the whole figure ADEB, which is the square of AB: Therefore the square of AB is equal to the squares of AC, CB, and twice the rectangle AC, CB. Where-if a straight line, &c. Q. E. D.

Cor. From the demonstration, it is manifest, that the parallelograms about the diameter of a square, are likewise squares.

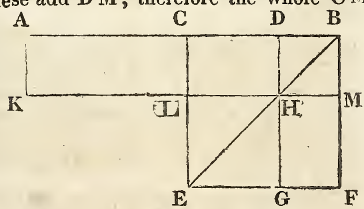
Let the line be 8, and the two parts 5 and 3 as before; then the square of (8) the whole is 64; and the sum of the squares of the parts (5 and 3) is 34; and twice the product or rectangle of the parts is 30; therefore the square of these parts, or 34 added to twice their rectangle, or 30, make 64, which is the same as the square of the whole, which was to be shown.

PROPOSITION V.

Theorem.—*If a straight line be divided into two equal parts, and also into two unequal parts; the rectangle contained by the unequal parts, together with the square of the line between the points of section, are equal to the square of half the line.*

Let the straight line AB be divided into two equal parts in the point C, and into two unequal parts at the point D; the rectangle AD, DB, together with the square of CD, is equal to the square of CB.

Upon CB describe the square CEFB, join BE, and through D draw DHG parallel to CE or BF; and through H draw KLM parallel to CB or EF; and also through A draw AK parallel to CL or BM: And because the complement CH is equal to the complement HF, to each of these add DM; therefore the whole CM



is equal to the whole DF; but CM is equal to AL, because AC is equal to CB; therefore also AL is equal to DF. To each of these add CH, and the whole AH is equal to DF and CH: but AH is the rectangle contained by AD, DB, for DH is equal to DB; and DF together with CH is the gnomon CMG; therefore the gnomon CMG is equal to the rectangle AD, DB: To each of these add LG, which is equal to the square of CD; therefore the gnomon CMG, together with LG, is equal to the rectangle AD, DB, together with the square of CD; but the gnomon CMG and LG make up the whole figure CEFB, which is the square of CB: Therefore the rectangle AD, DB, together with the square of CD, is equal to the square of CB. Wherefore if a straight line, &c. Q. E. D.

Cor. From this proposition it is manifest, that the difference of the squares of two unequal lines AC, CD, is equal to the rectangle contained by their sum and difference.

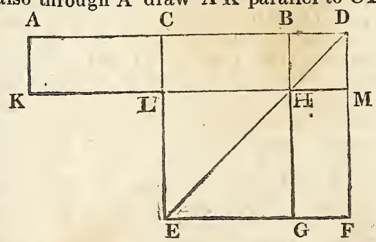
Let the whole line be 12, then each of the two equal parts will be 6. Again, let the unequal parts be 8 and 4, consequently the line between the points of section will be 2; then the rectangle of the unequal parts, namely, 8 and 4, is 32, and the square of 2, the line between the points of section, is 4; and this added to 32, makes 36, which is just equal to the square of 6, or half the line.

PROPOSITION VI.

Theorem.—*If a straight line be bisected, and produced to any point; the rectangle contained by the whole line thus produced, and the part of it produced, together with the square of half the line bisected, is equal to the square of the straight line, which is made of the half and the part produced.*

Let the straight line AB be bisected in C, and produced to the point D; the rectangle AD, DB, together with the square of CB, is equal to the square of CD.

Upon CD describe the square CEFD, join DE, and through B draw BHG parallel to CE or DF, and through H draw KLM parallel to AD or EF, and also through A draw AK parallel to CL



or DM: and because AC is equal to CB, the rectangle AL, is equal to CH; but

C H is equal to H F; therefore also AL is equal to H F: To each of these add C M; therefore the whole A M is equal to the gnomon C M G: And A M is the rectangle contained by A D, D B, for D M is equal to DB: therefore the gnomon C M G is equal to the rectangle AD, D B: Add to each of these L G, which is equal to the square of C B, therefore the rectangle A D, D B, together with the square of CB, is equal to the gnomon C M G and the figure L G: But the gnomon C M G and LG make up the whole figure C E F D, which is the square of C D; therefore the rectangle A D, D B, together with the square of C B, is equal to the square of C D. Wherefore, if a straight line, &c.

Let the line be 12, when it is bisected, each part will be 6; let it also be produced or increased to 16, then the rectangle contained by the whole or 16, and 4 the part produced, is 64: to which the square of 6 being added, makes 100; but this is just the square of 10, or the line made up of the half line and produced part, which was to be shown.

MECHANICS.

ON MECHANICAL AGENTS.

The powers which are usually employed on a great scale as the first movers of machinery, are, 1. The strength of men and animals; 2. The elastic force of steam and heated air; 3. The force of water; and 4. The force of wind.

As the three last of these agents are either already, or will be, treated of under the heads of Pneumatics, Hydraulics, and Chemistry, we shall only notice the first of them in this place.

ON THE STRENGTH OF ANIMALS.

The form and construction of the human body renders it peculiarly applicable as the first mover of machinery, and what it wants in strength is compensated in a great degree, by the skill and judgment with which it can be applied. When we consider the great number of cases in which it is preferable to employ the action of men rather than that of inanimate agents, and the still greater number in which it is out of our power to employ any other, it becomes a matter of the highest importance, both to workmen and to those who employ them, to ascertain the way in which the greatest quantity of work can be obtained from their exertions, with the least quantity of bodily fatigue, or with such a quantity of fatigue as they can easily bear from day to day, without injuring their corporeal functions.

Daniel Bernoulli indeed maintained, that the degree of fatigue is always proportional to the quantity of action by which it is produced; that whether he walks or carries a load, or draws, or pushes, or works at a winch, or raises a weight, he will always produce with the same degree of fatigue the same quantity of action, and therefore the same effect; and that the daily labour of a man, whatever be the work to which he is set, may be reckoned at 1,728,000 pounds raised through the height of one foot, or 60 pounds raised through the height of one foot in a second, when his day's labour amounts to eight hours. These opinions were adopted by almost all subsequent authors, on the authority of vague and inconclusive experiments, till the subject received a full investigation from the celebrated Coulomb, Amontons, and others.

According to M. Amontons, a man weighing 133 French pounds, ascended 62 French feet by steps in a minute, but was completely exhausted.

A sawyer, according to the same author, made 200 strokes of 18 French inches each, with a force of 25 pounds, in 145 seconds.

An ordinary man, according to Desaguliers, can turn a winch with the force of 30 pounds for 10 hours, with a velocity of $2\frac{1}{2}$ feet per second.

Two men, according to Desaguliers, working at a windlass with handles at right angles to each other, can raise 70 pounds more easily than one man can raise 30, an additional effect of five pounds being produced on the work of each man, in consequence of the uniform action arising from the handles being at right angles to each other.

A man may, according to the same author, exert a force of 80lbs. with a fly, when the motion is pretty quick..

A man may also, with a good pump, raise a hogshead of water 10 feet high in a minute, and continue the work for a whole day.

According to Dr. Robinson, a feeble old man raised 7 cubic feet of water, $=437\frac{1}{2}$ lbs. avoirdupoise, $11\frac{1}{2}$ feet high in a minute, for 8 or 10 hours a day, by walking backwards and forwards on a lever.

A young man, weighing 135 pounds, and carrying 30 pounds, raised $9\frac{1}{4}$ cubic feet of water, $=578\frac{1}{10}$ avoirdupoise, $11\frac{1}{2}$ feet high for 10 hours a-day without being fatigued.

The strength of men, and of all animals, is most powerful when directed against a resistance that is at rest: when the resistance is overcome, and when the animal is in motion, its force is diminished; lastly, with a certain velocity, the animal can do no work, and can only keep up the motion of its own body.

The effect of animal force, or the quantity of work done in a given time by any working animal, is greatest when the animal moves with one-third of the speed with which it is able only to move itself, and is loaded with four-ninths of the greatest load it is able to put in motion.

According to this estimate, a man who can move 120 lbs. and walk at the rate of 4 miles an hour, when working to the greatest advantage, should carry a load of 54 pounds, and walk at the rate of two feet in a second, or a mile and one third in an hour.

In raising a weight, a man will produce the greatest effect, when his weight is to that of his load as 4 to 3 nearly.

When a horse's work is estimated by the load he draws in a cart or waggon, a great reduction must be made, in order to compare the force he exerts with that which is necessary for raising a weight, by drawing it over a pulley. Though accurate experiments on the friction of wheel carriages are wanting, we probably shall not err much in supposing the friction, on a road, and with a carriage of the ordinary construction, to amount to a twelfth part of the load. If then, a horse draws a ton in a cart, which a strong horse will continue to do for several hours together, we must suppose his action the same as if he raised up the twelfth part of a ton (2240 lb.) or 186 lb. perpendicularly against the force of gravity. To raise a weight of 186 lb. therefore, at the rate of two miles, or two miles and a half an hour; (that is, 2·9, or 3·6 feet per second), may be taken as the average work of a strong draught horse in good condition.

On this subject, however, many more experiments are wanting; to determine, for instance, the friction of wheel carriages; the difference of the exertion required to walk on a horizontal plane, and on one of a given declivity; the quantity of work done in a given time by the same animal, carrying different loads. The difference between the effective exertion of a man's strength when he moves along with his load, and when he stands, as in turning a wheel; or sits, as in rowing a boat, &c.

MECHANICAL CONTRIVANCES USED IN THE CONSTRUCTION OF MACHINES.

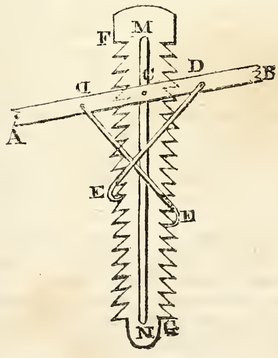
In all machines beyond the limits of the simple mechanical powers, the power of the first mover must be conveyed to the place where the work is to be performed, by means of mechanical contrivances, which vary according to the nature of the impelling power and the work to be performed, the respective localities of the first mover, and the working part of the machine. The skill of the engineer is is no way more conspicuous than in the intermediate machinery by which he transmits and modifies the action of the prime mover; and the general machine must derive its character of utility and durability from the simplicity of the intermediate machinery, and the judgment with which the individual contrivances are selected.

In order to convey some general idea of the composition of machines, we shall lay before our readers a description of some of the leading mechanical contrivances which are in constant use in machinery, and explain the methods by which the direction of motion may be any way changed, and by which one kind of motion may be converted into another.

Belts, Bands, and Ropes.—When it is required to convey the force of one wheel to another, the simplest of all methods is to connect them by means of leather belts passing over the circumference of each. The great advantage of belts is, that by means of them we may convey the motion of one wheel to another at a very great distance, which could not be done without a considerable expense by wheels and pinions; but they have the disadvantage of stretching so as to become loose, and thus lose their power of turning the wheel. This evil, however, may be instantly remedied by shortening them, or by increasing the friction by means of chalk. Sometimes this evil is remedied by having grooves of different diameters in one or both of the wheels; and when the belt or rope becomes slack, it is shifted to the following groove; but this can be permitted only in machines, such as turning lathes, where a change of velocity is of no importance. When ropes are used, they always move in grooves cut in the circumference of the sheaves or wooden wheels round which they pass.

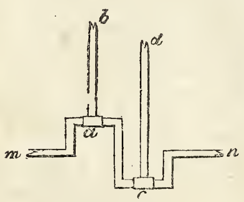
When there is a great strain upon the machinery, and when its motions are required to be regular,' belts and ropes cannot safely be employed. *Chains* are therefore substituted in their place with peculiar advantage.

The Lever of Lagaroust.—This contrivance, which has the property of producing a continued rectilineal motion from an alternating circular motion, is shown in the following figure.



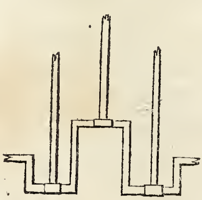
The lever A B moves round an axis C attached to a fixed beam M N. A toothed rack or beam F G, is capable of descending and ascending freely by the action of the hooks or teeth at the end of the two secondary levers D E, D′ E′ fixed at the points D, D′ of the great lever A B. When the end A descends, the hook E′ falls down upon the teeth below it, while the simultaneous ascent of the end B C causes the hook E to draw upwards the beam F G. By now depressing B C, the hook E falls down upon the teeth below it, while the ascent of A C causes the hook E′ to draw upwards the beam F G. The very same contrivance may be employed to give a circular motion to a wheel, having its circumference furnished with teeth like those upon F G.

Crank.—When the communicating parts have a permanent connection, it is necessary to employ other contrivances, besides the foregoing, among which are the Crank, which is one of the simplest and most durable of any for conveying motion. It is in principle the same as a wheel with the power applied at or near its circumference. A *double crank* is shown in the following figure.

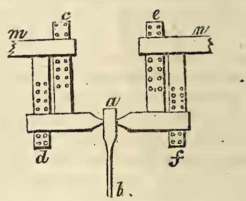


Where *m n* is the revolving axis, which by means of the double crank, communicates a reciprocating motion to the two beams *a b*, *c d*, the one ascending when the other is descending.

A *triple crank* is shown in the following figure,

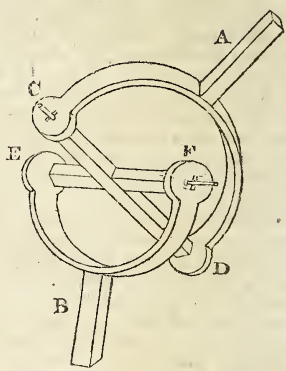


where three beams are made to ascend and descend; but the planes passing through each of the three cranks, must be inclined 120° to one another. A changeable crank, in which the radius is variable, is shown in the following figure:



where *m n* is the axis, and *a b* the beam, which can be set to different distances from *m n*, by drawing up the four parallel bars, *c*, *d*, *e*, *f*, and fixing them in any position by pins passing through the small holes.

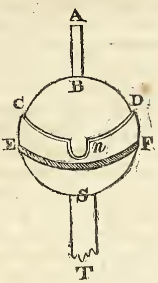
Hooke's universal joint.—This ingenious contrivance, which is shown in the following figure,



consists of two shafts, or axis, A, B, terminating in a semicircle, and connected by means of a cross C D, E F. As the branches C D, E F, have a motion round their pivots at C D, E, and F, it is obvious that when the shaft A is turned round, a similar motion will also be communicated to the shaft B. This joint may be used when the inclination of the shaft does not exceed 40°, or rather 140°, its supplement. When the inclination of the shafts is between 50° and 90°, *a double universal joint* is employed. In this case there are two crosses, the extremities of which move on their pivots in the semicircles at the ends of the shafts. These joints may also be constructed with four pins, fastened at right angles upon the circumference of a hoop, or solid ball.

The *sun* and *planet* wheel is also employed for communicating motion to machines; but as we have fully explained this contrivance at page 227, it is unnecessary to describe it here.

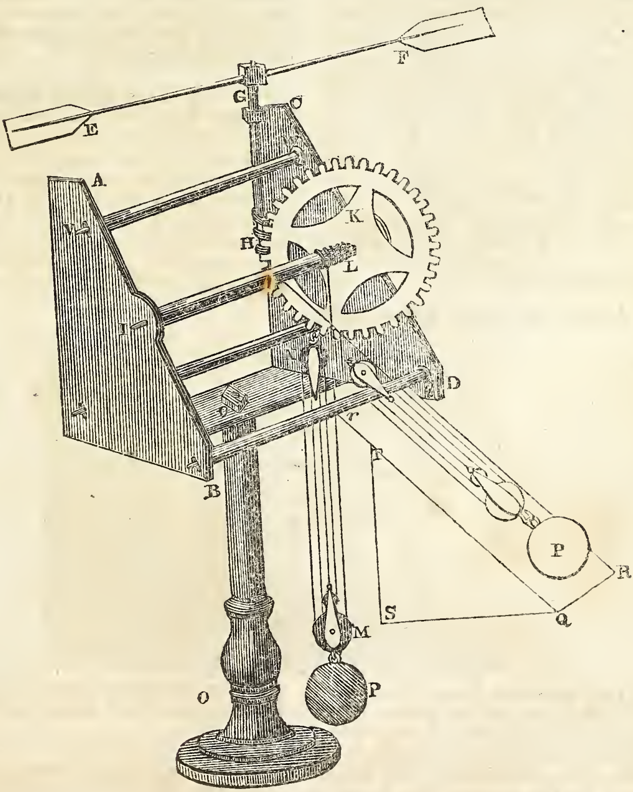
Ball and Socket.— Although the ball and socket is not used in general machinery, yet we may regard it as a mechanical contrivance, by which two parts of a machine are permanently connected. The object of it is to give a motion in various directions to one axis, while the other remains fixed. This is generally done in telescopes, by the joint effect of a horizontal and a vertical movement; but when the telescope is not heavy, a ball and socket is the simplest and most commodious contrivance. It is represented in the following figure,



where B is a ball of brass, fixed at the lower extremity of the axis A B, on which a telescope or any other body is supported. This ball is of the same diameter as the interior diameter of the socket or cap C S D, with which the lower axis S T is terminated. This socket consists of two parts, C E F D, E F S, the former of which can be removed, slackened, or tightened, by turning the milled circumference E F. On the bottom of the socket is placed a piece of cork, against which the lower part of the ball B presses, so that whenever the ball moves too loosely in the socket, it may be pressed against the elastic cork, by turning E F, which draws the ball downwards, by which means its motion is rendered as stiff as we choose. In the upper edge of the moveable part C D, a groove *n* is cut, to allow the axis A B to come into a position at right angles to S T.

A MACHINE IN WHICH ALL THE MECHANICAL POWERS ARE UNITED.

The following figure represents a machine, in which all the simple mechanical powers are combined.

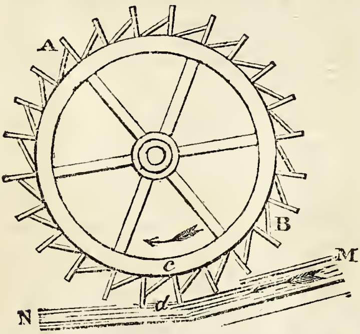


It consists of a frame A B C D fastened upon the stand O *o* by the nut *o*, and kept together by the pillars V W and B *q*. The piece E F is first fitted to the frame, having vanes E F, which may be either moved by the wind, or by a cord fastened at F. This part represents the lever, whose fulcrum is G. A perpendicular axis G A is joined to this lever, and carries the endless screw H, which may be considered as a wedge. This endless screw works in the teeth of the wheel K, which is the wheel and axle; and when K is turned round, it winds upon the axle I L the cord L M, which passing round the tackle of pulleys M N, raises the weight P. In order to include the inclined plane in this combination, we must add the plane R Q *r q*, and make it rest on the ground at Q R, and on the pillar B *q* at *q r*. When the weight P is placed on this plane, the power will be farther increased in the ratio of Q T to T S. The power gained by this combination will be found, by comparing the space described by the point F, with the height through which the weight rises in any determinate number of revolutions of F.

HYDRAULICS.

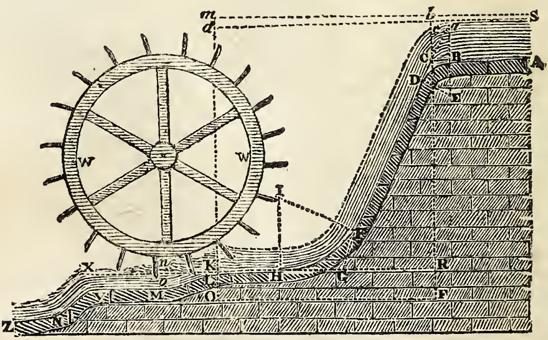
ON UNDERSHOT WATER WHEELS.

An undershot water-wheel is a wheel with a number of floatboards, or plane surfaces arranged round its circumference, for the purpose of receiving the impulse of the water, which is conveyed to the under part of the wheel from an inclined canal. A wheel of this kind of the ordinary construction, is shewn in the following figure,



where A B is the wheel with 24 floatboards, *c d*, a floatboard receiving the impulse of the water, which moves with great velocity in consequence of having fallen from a considerable height down the inclined mill-course M N. The principal points to be attended to in the construction of undershot wheels, are the construction of the mill course, the number, form, and position of the floatboards, and the velocity of the wheel in relation to that of the water when the effect is a *maximum*. The following rules for the construction of mill courses are given in the Appendix to Ferguson's Lectures, vol. ii.

" As it is of the highest importance to have the height of the fall as great as possible, the bottom of the canal, or dam, which conducts the water from the river, should have a very small declivity; for the height of the water-fall will diminish in proportion as the declivity of the canal is increased. On this account, it will be sufficient to make A B slope about one inch in 200 yards, as in the following figure,



taking care to make the declivity about half an inch for the first 48 yards, in order that the water may have a velocity sufficient to prevent it from flowing back into the river. The inclination of the fall, represented by the angle G C R, should be 25° 50′; or C R, the radius, should be to G R, the tangent of this angle, as 100 to 48, or as 25 to 12;* and since the surface

* A tangent is a line touching a circle, or any other curve; and the tangent of an angle is the side of a triangle, which is perpendicular to the side of it that is made radius.

of the water $S\,b$ is bent from $a\,b$ into $a\,c$, before it is precipitated down the fall, it will be necessary to incurvate the upper part B C D of the course into B D, that the water at the bottom may move parallel to the water at the top of the stream. For this purpose, take the points B, D, about 12 inches distant from C, and raise the perpendiculars B E, D E: the point of intersection E will be the centre, from which the arch B D is to be described; the radius being about $10\frac{1}{6}$ inches. Now, in order that the water may act more advantageously upon the floatboards of the wheel W W, it must assume a horizontal direction H K, with the same velocity which it would have acquired when it came to the point G: But in falling from C to G, the water will dash upon the horizontal part H G, and thus lose a great part of its velocity; it will be proper, therefore, to make it move along F H an arch of a circle, to which D F and K H are tangents in the points F and H. For this purpose make G F and G H each equal to three feet, and raise the perpendiculars H I, F I, which will intersect one another in the point I, distant about 4 feet 9 inches and $\frac{4}{10}$ths from the points F, and H, and the centre of the arch F H will be determined. The distance H K, through which the water runs before it acts upon the wheel, should not be less than two or three feet, in order that the different portions of the fluid may have obtained a horizontal direction; and if H K be much larger, the velocity of the stream would be diminished by its friction on the bottom of the course. That no water may escape between the bottom of the course K H and the extremities of the floatboards, K L should be about three inches, and the extremity *o* of the floatboard *n o* should be beneath the line H K X, sufficient room being left between *o* and M for the play of the wheel, or K L M may be formed into the arch of a circle K M concentric with the wheel. The line L M V, called by M. Fabre, the *course of impulsion*, should be prolonged, so as to support the water as long as it can act upon the floatboards, and should be about 9 inches distant from O P, a horizontal line passing through O, the lowest point of the fall; for if O L were much less than 9 inches, the water having spent the greater part of its force in impelling the floatboards, would accumulate below the wheel and retard its motion. For the same reason, another course, which is called by M. Fabre, the *course of discharge* should be connected with L M V by the curve V N, to preserve the remaining velocity of the water, which would otherwise be destroyed by falling perpendicularly from V to N. The course of discharge is represented by V Z, sloping from the point O. It should he about 16 yards long, having an inch of declivity in every two yards. The canal which reconducts the water from the course of discharge to the river, should slope about 4 inches in the first 200 yards, 3 inches in the second 200 yards, decreasing gradually till it terminates in the river. But if the river to which the water is conveyed, should, when swollen by the rains, force the water back upon the wheel, the canal must have a greater declivity, in order to prevent this from taking place. Hence it will be evident, that very accurate levelling is necessary for the proper formation of the mill course."

The general ideas contained in the preceding constructions appear to have been first suggested by Du Buat, and afterwards fully explained by M. Fabre, in his *Traite sur les Machines Hydrauliques.*

The diameters of undershot wheels must in general be accommodated to the nature of the machinery which they are to put in motion. If a great velocity is necessary, the wheel should for this purpose be made of a less diameter than would otherwise be adviseable; but if a great velocity is not required, the diameter of the wheel ought to be considerable.

M. Pitot, one of the earliest writers who attended to this subject, recommended that the number of floatboards should be equal to 360° divided by the arch of the circle plunged in the canal, and that their depth should be equal to the *versed sine* of that arch.* The slightest consideration, however, is sufficient to convince us that the number of floatboards obtained by this rule is greatly too small. M. Du Petit, Vandin, and afterwards M. Fabre, have, on the other hand, maintained, that the greatest possible number of floatboards should be used, provided the wheel is not too much loaded by them.

In Mr. Smeaton's model, by which his experiments were performed, the diameter of the wheel was 24 inches, and the number of floatboards 24. When the number was reduced to 12, a diminution in the effect was produced on account of a greater quantity of water escaping between the floats and the floor; but a circular sweep being adapted thereto of such a length, that one float entered the curve before the preceding one quitted it, the effect came so near to the former, as not to give hopes of advancing it, by increasing the number of floats beyond 24 in this particular wheel.

The experiments of Bossut were made with a wheel, whose exterior diameter was

* The versed sine of an arch is that part of the diameter which is intercepted between the circle and the chord, or straight line, which will cut off the arch from the rest of the circle.

3 feet 1 inch and 10 lines. It was used successively with 48, 24, and 12 floatboards directed to the centre. They were exactly 5 inches wide, and from 4 to 5 inches high. The edges and the extremities of the floatboards were distant about half a line from the bottom and sides of the inclined canal in which the wheel was placed, and the arch plunged in the water was 24° 54′. When this wheel was tried, it made $33\frac{1}{2}$ turns in a minute, when it had 48 floatboards, and when the weight raised was 12 pounds. When 24 floatboards were put on, it made only 29 turns in a minute, the weight raised being the same; and when 12 floatboards were used, it made no more than $25\frac{1}{2}$ turns in a minute. The velocity of the water in the canal which had a declivity of $10\frac{1}{2}$ feet in 50, was 300 feet in 33 seconds. Hence Bossut concludes, that the wheel ought to have at least 48 floatboards, whereas wheels 20 feet in diameter, and with only 25° or 30° of the circumference immersed, have generally only 40 floatboards.

When wheels are moved by a river, they ought to have a different number of floatboards. In order to find the number, M. Bossut used a different wheel, in which the floatboards were so placed that he could set them at any inclination to the radius, and employ any number of them at pleasure. The exterior diameter was 3 feet, the width of the floatboards 5 inches, and their height 6 inches. This wheel was made to move in a current from 12 to 13 feet wide, and in a depth of water of from 7 to 8 inches. The floatboards were plunged four inches in the water, so that the circumstances were the same as in an open river. When 24 floatboards were used, a load of 40 pounds was raised with a velocity of $15\frac{28}{48}$ turns in 40 seconds; whereas when 12 floatboards were used, the velocity with which the same load was raised was only $13\frac{15}{48}$ turns in the same side. When 48 floatboards were put on, 24 pounds were raised, with a velocity of $27\frac{19}{48}$ turns in a minute; and 24 floatboards raised the weight with a velocity of $27\frac{7}{48}$, the difference being perfectly trifling. Hence 24 floatboards at least should be used in cases of this kind. A smaller number would be sufficient, if a greater arch of the wheel were plunged in the stream. In practice, it was the general custom to use only 8 or 10 floatboards, and sometimes fewer, on wheels placed in rivers; but the number ought to have been from 12 to 18.

From theoretical considerations, M. Pilot has shewn, that floatboards should *always* be a continuation of the radius; but this rule is found to be quite incorrect in practice. The advantages arising from inclining the floatboards, were first pointed out, in 1753, by Deparcieux, who shews, that the water will thus heap up upon them, and acts by its weight as well as by its impulse. This opinion has been amply confirmed by the experiments of Bossut with the wheel already mentioned, moving in a canal where the velocity of the water was 300 feet in 27 seconds. When the floatboards were a continuation of the radius, a weight of 34 pounds was raised with a velocity of $20\frac{26}{48}$ turns in 40 seconds. When their inclination was 8°, the same load was raised with a velocity of $19\frac{20}{48}$ in 40 seconds. When the inclination was 12°, the velocity was $19\frac{40}{48}$ in 40 seconds; and when the inclination was 16°, the velocity was $20\frac{24}{48}$ turns in 40 seconds, nearly the same; but still a little less than when the floatboards were a continuation of the radius. Hence it follows, that a wheel placed upon canals which have little declivity, and in which the water is at liberty to escape easily after the impulse, the floatboards ought to be a continuation of the radius.

The same wheel being placed in the current already mentioned, viz. from 12 to 13 feet wide, and from 7 to 8 inches deep, floatboards which were a continuation of the radius, raised 40 pounds with a velocity of $13\frac{17}{48}$ turns in 40 seconds. With those inclined 15°, the number of turns in the same time was $14\frac{21}{48}$; with those inclined 30°, the number was $14\frac{22}{48}$; and with those inclined 37°, the number was $14\frac{15}{48}$. Hence it follows, that the most advantageous obliquity is, in this case, about 15 or 30 degrees. The difference of effect, however, appears to be very trifling, particularly beyond 15°. M. Fabre is of opinion, that when the velocity of the stream is 11 feet per second or greater, the inclination should never be less than 30°; that, as the velocity diminishes, the number of floatboards should diminish in proportion; and that when the velocity is 4 feet or under, the floatboards should be a continuation of the radius. The experiment of inclining the floatboards a little in the opposite direction, has not been tried by any of the authors whom we have quoted, but we think it worth trying, as it might increase the effect, by allowing the water to escape more readily from below the floatboards.

In order to determine the ratio between the velocity of the wheel and that of the water which drives it, Parent and Pitot considered only the action of the fluid upon one floatboard, and consequently they made the force of impulsion proportional to the square of the relative velocity, or to the square of the difference between the velocity of the stream and that of the floatboard. Desaguliers, Maclaurin, Lambert, Atwood, Du Buat, and Dr. Robinson, have gone upon the same principle, and have therefore fallen into the same error, of making the velocity of the wheel ⅔ of the velocity of the current, when the effect is a maximum The Chevalier de Borda, whose valuable Memoirs have been too much overlooked by later writers, has, however, corrected this error. He has shewn, that the supposition is perfectly correct when the water impels a single floatboard; for as the number of particles which strike the floatboard in a given time, and also the momentum of these, are each as the relative velocity of the floatboards, the momentum must be as the square of the relative velocity; that is, the momentum varies as the square of the relative velocity. But as the water acts on more than one floatboard at once, the number acted upon in a given time will be as the velocity of the wheel, or inversely as the *relative* velocity; for if we increase the relative velocity, the velocity of the water remaining the same, we must diminish the velocity of the wheel; consequently, the momentum will vary as the relative velocity.

"The velocity of the stream," says Mr. Smeaton, "varies at the greatest between one-third and one-half that of the water; but in all the cases in which most work is performed in proportion to the water expended, and which approach the nearest to the circumstances of great works, when properly executed, the maximum lies much nearer to *one-half* than *one-third;* one half seeming to be the true maximum, if nothing were lost by the resistance of the air, the scattering of the water carried up by the wheel, &c. all which tend to diminish the effect, consequently the maximum would be greater if these did not take place." Smeaton considers 5 to 2 as the best general proportion.

A result, nearly similar to this, was deduced from the experiments of Bossut. He employed a wheel whose diameter was three feet. The number of floatboards was at one time 48, and at another 24, their width being five inches, and their depth six. The experiments with the wheel, when it had 48 floatboards, were made in the inclined canal, in which the velocity was 300 feet in 27 seconds. The experiments with the wheel, when it had 24 floatboards, were made in a canal contained between two vertical walls, 12 or 13 feet distant. The depth of the water was about 7 or 8 inches, and its mean velocity about 2740 inches in 40 seconds. The floatboards of the wheel were immersed about four inches in the stream.

The following are the other results which Mr. Smeaton deduced from his experiments. He found, that in undershot wheels, the power employed to turn the wheel is to the effect produced as 3 to 1; and that the load which the wheel will carry at its maximum, is to the load which will totally stop it, as 3 to 4. The same experiments show, that the impulse of the water on the wheel, in the case of a maximum, is more than double of what is assigned by theory; that is, instead of four-sevenths of the column, it is nearly equal to the whole column. In order to account for this, Mr. Smeaton observes, that the wheel was not, in this case, placed in an open river, where the natural current, after it had communicated its impulse to the float, has room on all sides to escape, as the theory supposes; but in a conduit or race, to which the float being adapted, the water could not otherwise escape than by moving along with the wheel. He likewise remarks, that when a wheel works in this manner, the water, as soon as it meets the float, receives a sudden check, and rises up against it like a wave against a fixed object; insomuch, that when the sheet of water is not a quarter of an inch thick before it meets the float, it will not act upon the whole surface of a float, whose height is three inches. Were the float, therefore, no higher than the thickness of the sheet of water, as the theory supposes, a great part of the force would be lost by the water dashing over it. Mr. Smeaton likewise deduced, from his experiments, the following maxims.

1. That the virtual or effective head being the same, the effect will be nearly as the quantity of water expended.

2. That the expense of water being the same, the effect will be nearly as the height of the virtual or effective head.

3. That the quantity of water expended being the same, the effect is nearly as the square of the velocity.

4. That the aperture being the same, the effect will be nearly as the cube of the velocity of the water.

UNDERSHOT WHEELS MOVING AT RIGHT ANGLES TO THE STREAM.

Undershot wheels have sometimes been constructed like windmills, having large inclined floatboards, and being driven in a plane perpendicular to the direction of the current. Albert Euler, who has examined theoretically this species of water wheel, concludes that the effect will be twice as great as in the common undershot wheels, and that in order to produce the effect, the velocity of the wheel, computed from the centre of the impression, should be to the velocity of the water as radius is to thrice the sine of the inclination of the floatboards to the plane of the wheel. When the inclination is 60°, the ratio will be at 5 to 13 nearly, and when it is 30°, it will be nearly as 2 to 3. In this kind of wheel, a considerable advantage may also be gained by inclining the floatboards to the radius. In this case, the area of the floatboards ought to be much greater than the section of the current, and before one floatboard leaves the current, the other ought to have fairly entered it. This construction may be employed with advantage in deep rivers that have but a small velocity.

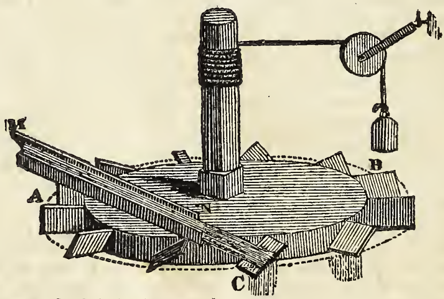
BESANT'S UNDERSHOT WHEEL.

This wheel, invented by Mr. Besant, of Brompton, is constructed in the form of a hollow drum, to resist the admission of water; but its principal peculiarity consists in the arrangement of floatboards in pairs on the periphery of the wheel. Each floatboard is set obliquely to the plane of the wheel's motion, and the corresponding floatboard is inclined at the same angle, but in an opposite direction, the plane of the wheel bisecting the angle formed by the two floatboards. The acute angle which the one floatboard forms with its corresponding one is open at the vertex; but one of the floatboards extends beyond the other. By this construction, the resistance from the tail water is diminished; but so far as we know, the machine has never come into use.

HORIZONTAL WATER WHEELS.

Horizontal water wheels differ in no respect from common undershot wheels, except in the circumstance of their extremities being placed vertically. The mill-course is constructed nearly in the same manner for both. The principal object of this form of the water wheel is to save machinery by placing the mill-stone directly on the vertical shaft of the wheel. The water must therefore move with a very great velocity, so as to enable the mill-stones to perform their work. The water is turned into a horizontal direction before it strikes the floatboards, which may be either vertical or inclined to the radius, as in undershot wheels.

Horizontal wheels are often constructed so that the floatboards have a very great inclination to the radius. In this case, the water is not turned into a horizontal direction, but is made to strike the floatboards perpendicularly, as represented in the following figure,



where A B is the wheel, M N the mill-course discharging its contents perpendicularly upon the floatboard C, which ought to have a surface more than twice the area of the section of the stream.

In the southern departments of France, the floatboards are made of a curvilineal form, so as to present a concave surface to the stream.

The Chevalier Borda remarks, that in theory a double effect is produced when the floatboards have this form; but that the advantage is not so great in practice, from the difficulty of making the fluid enter and leave the course in a proper manner. They appear, however, to be decidedly superior to those in which the floatboards are plane, as the water acts by its *weight* as well as by its *impulsive* force. The ratio of the effects in the two cases, with five or six feet of fall, is nearly as 3 to 2. An advantage may be gained by dividing the current, and throwing it in separate portions upon different floatboards.

WHEELS WITH SPIRAL FLOATBOARDS.

In some of the southern provinces of France, a conical horizontal wheel with spiral floatboards is frequently used. It has the form of an inverted cone, with a number of spiral floatboards winding round its surface, so as to be nearer one another at the smaller or lower end of the cone, than at the larger or upper end. When the water has acted upon these floatboards by its impulse, it descends along the spirals, and continues to drive the machine by its weight.

Dr. Robinson describes another wheel with spiral floatboards, which was moved by a screw. "It was," he says, "a long cylindrical frame, having a plate standing out from it about a foot broad, and surrounding it with a very oblique spiral like a cork screw. This was plunged about ⅕th of its diameter (which was about 12 feet), having its axis in the direction of the stream. By the work which it was performing, it seemed more powerful than a common wheel, which occupied the same breadth of the river."

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF THE LATE DR. HUTTON.

(Continued from page 258.)

Such were among the invaluable but short-lived labours of Dr. H. in the Royal Society: and here it may be proper to state the circumstances by which they were unfortunately terminated.

When Dr. Hutton first entered the Society, Sir John Pringle was the President. He was a person of great acquirements, and eminently well qualified to fill the chair of Newton. He always manifested a particular regard for the Doctor, which probably excited the jealousy of many persons, who were not attached to mathematical investigations: among the members of this description, was Mr. (afterwards Sir Joseph) Banks, a gentleman too well known to render it necessary to add any thing further here concerning him, except that he had acquired sufficient influence over the majority of the members of the Society to obtain his election as President, upon the resignation of Sir John Pringle. Dr. H. had for some time held the office of Foreign Secretary with the greatest credit; but the new President, who wished the situation to be filled by a friend of his own, procured a vote to be passed by the Society, that it was requisite this secretary should reside constantly in London; a condition with which the Doctor could not possibly comply; and he therefore resigned the situation. Many of the most valuable members of the Society, however, warmly espoused Dr. H.'s cause, and discontinued their accustomed attendance at the usual periodical meetings: among the number may be mentioned Dr. Horsley, Dr. Maskelyne, Baron Maseres, and many other distinguished characters; who, finding that the disciples of Newton were always outvoted by those of Linnæus, retired, with Dr. Hutton, from the Society. When the mathematicians were preparing to secede, Dr. Horsley expressed himself in the following energetic words:—"Sir, (addressing himself to the President,) when the hour of secession comes, the President will be left with his train of feeble amateurs and that toy—(pointing to the mace on the table,) the ghost of the Society where philosophy once reigned, and Newton was her minister."

This secession took place in 1784, since which period very few papers on mathematical subjects have appeared in the "*Philosophical Transactions;*" and it is even said, that the late President uniformly opposed the admission of mathematicians into the Royal Society, unless they were persons of rank.

Although Dr. Hutton's retirement deprived him of the great stimulous to exertion which such a Society must have afforded, he still continued to give to the world, from time to time, various valuable works. In 1785 he published his "*Mathematical Tables,*" and in 1786 appeared his "*Tracts on Mathematical and Philosophical Subjects,*" in three volumes, which contain much new and valuable matter. In the following year, he published his "*Elements of Conic Sections,*" with select exercises in various branches of mathematics and philosophy, for the use of the Royal Military Academy at Woolwich. This work was warmly patronized by the Duke of Richmond, then Master-general of the Ordnance, who, on that occasion, presented Dr. Hutton at court to his Majesty.

In 1795 appeared his "*Mathematical and Philosophical Dictionary,*" in two large volumes, quarto, which was the result of many years' preparation, and has since advanced to a second edition. It has supplied all subsequent works of the kind, and even the most voluminous Cyclopædias, with valuable materials, both in the sciences, and in scientific biography.

His next publication was "*A Course of Mathematics,*" in two volumes, octavo, composed for the use of the students of the Royal Military Academy; which has since become a standard work in many eminent schools, both in Great Britain and America.

In the year 1803, he undertook the arduous task of abridging the "*Philosophical Transactions,*" in conjunction with Dr. Pearson and Dr. Shaw. Dr. Hutton is said to have executed the chief part of the work, and to have received for his labour no less a sum than six thousand pounds. It was completed in 1809, and the whole comprised in eighteen quarto volumes. About the same period was published his translation of "*Montucla's Recreations in Mathematics and Natural Philosophy,*" and an improved edition of the same work appeared in 1814.

In 1806 the Doctor became afflicted with a pulmonary complaint, which confined him for several weeks; but in the following year he resumed his professional duties. His medical friends, however, advised him to retire from the labours of the Academy, as soon as it might be deemed convenient; and, in consequence of an application to this effect, the Master-general and Board of Ordnance acceded to his wishes, and manifested their approbation of his long and meritorious services, by granting him a pension for life, of £500 per annum. This annuity, together with a large property which he had realised, chiefly by his publications, enabled him to retire in affluent circumstances. But in his retirement, his constant amusement continued to be, the cultivation and diffusion of useful science. He officiated for some time, every half-year, as the principal examiner to the Royal Military Academy, and also to the East India College, at Addiscombe.

During this period, as well as previously, he was indefatigable in kind offices, especially in promoting the interest of scientific men, and recommending them to situations, where their talents might prove most useful both to themselves and to their country. To his recommendations, as well as to his instructions, our most eminent scientific institutions have been chiefly indebted for their Professors of Mathematics during the last thirty years.

His death was caused by a cold, which brought on a return of his pulmonary complaint. His illness was neither tedious nor painful; and his valuable life terminated on the 27th of January, 1823, in the eighty-sixth year of his age. His remains were interred in the family vault at Charlton, in Kent.

It is worthy of remark, that only three days previous to his death, he received certain scientific questions from the corporation of London, which he answered immediately in the most masterly manner. These questions related to the intended arches of the new London bridge; and his paper on the subject is considered not only as a valuable document, but also highly interesting, as being the last production of this great man, and at such a period of his advanced age and illness.

During the last year of Dr. Hutton's life, many of his scientific friends, wishing to possess as correct and lasting a resemblance of his person as his valuable works exhibit of his mind, entered into a subscription for a marble bust, from which casts might be taken in any number that might be required. This bust has been admirably executed by Mr. Sebastian Gahagan. The subscription was supported by many of the Doctor's early pupils, and other eminent men, who seemed emulous in manifesting their gratitude and esteem. The sums subscribed having been found greatly to exceed the disbursements, the committee resolved to employ the surplus in executing a medal; to contain, on one side, the head of Dr. Hutton, and, on the other, emblems of his discoveries on the force of gunpowder, and the density of the earth. These medals have been finely executed by Mr. Wyon, and one has been given to each subscriber to the bust.

About three months before his death, the bust was presented to the Doctor; but the medals were finished only in time to be presented to his friends who attended his funeral.

Dr. Hutton bequeathed his marble bust to the Philosophical Society of Newcastle. It is to be placed in their new and splendid Institution, where it will be long regarded with pride and veneration. He always manifested a laudable affection for his native place, of which he gave a proof soon after his retirement from Woolwich, by investing sums of money for the perpetual support of education, &c. at Newcastle. His benevolence was extensive. To merit in distress, and more especially to the votaries of science, he was always a kind friend and benefactor.

Dr. Hutton was twice married: his surviving family consist of a son and two daughters. The former was educated at the Royal Military Academy, and at an early age he obtained a commission in the Royal Regiment of Artillery, and is now a Lieut.-General in the army. General Hutton is also a member of several learned societies, and has been honoured with the degree of D.C.L.

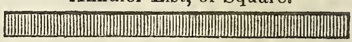
ARCHITECTURE.

MOULDINGS.

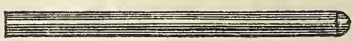
Mouldings are those parts which project beyond the face of a wall, a column, &c. and are employed as ornaments in most Architectural operations.

The regular mouldings are eight in number, and are represented by the following figures.

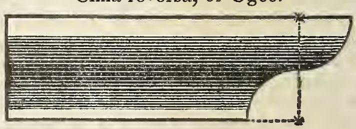
Annuler List, or Square.



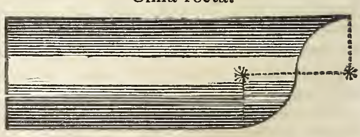
Astragal, or Bead.



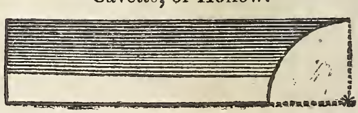
Cima reversa, or Ogee.



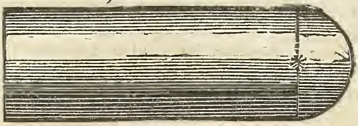
Cima recta.



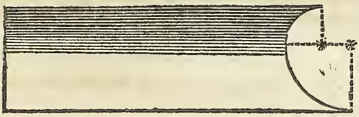
Cavetto, or Hollow.



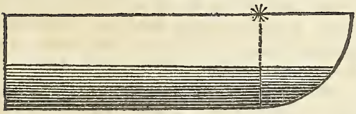
Ovolo, or Quarter round.



Scotia.



Torus.



The forms of all mouldings are referred to a section at right angles to their longitudinal direction, when prismatic, or passing through the axis, if annular; and this is simply denominated the *section*, on account of its frequent use, as oblique sections only occur in mitres. The names of mouldings depend upon their form and situation.

If the section is a semicircle which projects from a vertical diameter, the moulding is called an Astragal, Bead, or Torus; if a torus and bead be both employed in the same order of architecture, they are only distinguished by the bead being the smallest. The tori are generally employed in bases and capitals.

If the moulding be convex, and its section be the quarter of a circle or less, and if the one extremity project beyond the other equal to its height, and the projecting side be more remote from the eye than the other, it is termed a Quarter-Round; this in Roman architecture, is always employed above the level of the eye.

If the section of a moulding be concave, but in all other respects the same as the last, it is denominated a Cavetto. They are never employed in bases or capitals, but frequently in entablatures.

If the section of a moulding is partly concave and partly straight, and if the straight part be vertical and a tangent to the concave part, and if the concavity be equal or less than the quadrant of a circle, the moulding is denominated an Apophyge, Scape, Spring, or Conge: it is used in the Ionic and Corinthian orders for joining the bottom of the shaft to the base, as well as to connect the top of the fillet with the shaft under the astragal.

If the section be one part concave and the other convex, and so joined that they may have the same tangent, the moulding is named a Cymatium; but Vitruvius calls all crowning or upper members cymatiums, whether they resemble the one now described or not.

If the upper projecting part of the cymatium be a concave, it is called a Cima-recta, they are generally the crowning members of cornices, but are seldom found in other situations.

If the upper projecting part of the cymatium be convex, it is called a cima-reversa, and is the smallest in any composition of mouldings, its office being to separate the larger members: it is seldom used as a crowning member of cornices, but is frequently employed with a small fillet over it, as the upper member of architraves, capitals, and imposts.

If the section of the moulding be the two sides of right angles, the one vertical, and the other of course horizontal, it is termed a *fillet*, *band*, or *corona*. A fillet is the smallest rectangular member in any composition of mouldings. Its altitude is generally equal to its projection; its purpose is to separate two principal members, and it is used in all situations under such circumstances. The corona is the principal member of a cornice. The beam or facia is a principal member in an architrave as to height, but its projection is not more than that of a fillet.

METHOD OF REPRESENTING TREES UPON POTTERY.

When the pottery has received from the workman its form, and after it has acquired some degree of consistence, the surface, on which the representation of trees is desired, must be steeped in a vessel, containing a solution of argile (clay) very much diluted, either coloured or not as may be required, until it is perfectly moist. This process will give to the pot, the same colour, as the clay, in which it has been steeped.

When this process is finished, in order that trees may be produced, it is sufficient, whilst the solution of clay is yet moist, and even at the moment when taken from the steeping vessel, to place lightly with a brush in different parts of the surface spots of whatever colour the trees may be required; each spot producing a tree of a large or small size according to the quantity of colour used upon each, and also to the manner in which the workman acts with the hand in which the pot is held.

The trees may be of any colour whatever, but the most agreeable colour is bistre, which is thus composed: take one pound of manganese calcined; 6 ounces of iron rust, or 1 lb of iron ore; and three ounces of ground flint. The manganese and the iron rust, or iron ore, must be bruised separately in a mortar, after which they must be put together into a crucible and calcined. The mixture thus prepared may again be bruised, and afterwards put into a small tub of water, in order to render it moist.

For blue, green, or other colours, the materials which are generally used for producing them may be prepared in the same manner as above. But to apply these different colours to the articles, it is necessary, as in ordinary painting, to use a mordant instead of moistening with water.

The best mordant that can be employed is urine, and the essence, or juice of tobacco.

In order to obtain tobacco water for this purpose, it is sufficient to steep two ounces of good leaf tobacco in a bottle of cold water for 10 or 12 hours, or simply to infuse two ounces of tobacco in a bottle of hot water.

SOLUTIONS OF QUESTIONS.

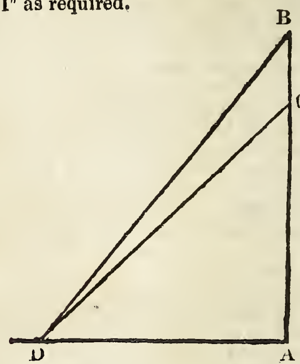
Quest. 38, *answered by* Mr. Graham, *Teacher, Liverpool, (the proposer).*

Put x equal one of the lenear edges of the regular tetraedron, then arises the following equation $2\,x\sqrt{\frac{3\,x^2}{4}}=6x$, reduced, gives x equal $2\sqrt{3}$ the lenear edge of the tetraedron. Thus, at page 185, Dr. Hutton's large mensuration, the content of the tetraedron is $2\sqrt{6}$, and the diameter of the circumscribed sphere is $3\sqrt{2}$. Then $3\sqrt{2}$ cubed and multiplied into ·5236 (the solidity of a sphere whose diameter is 1), gives 39·9868 solid feet, which is evidently the least circumscribed sphere: also the solid content of the tetraedron taken from the content of the circumscribed sphere is 35.0878 solid feet of gold. Then, 1 feet : 18888 oz. av. $\times\frac{350}{384}$: : 35·0878 feet : 604231·1583 oz. Troy, at 3*l.* 17*s.* 10½*d.* per oz. comes to 2413148*l.* 3*s.* 9*d.* Again, the content of the pebble tetraedron is $2\sqrt{6}$ feet, multiplied into 2700 oz. av. (the weight of a solid foot of pebble) is 13227·2446 oz. av. which, added to the weight of the gold in avoidupoise ounces (662738·5169), gives 675965·7615 oz av. the weight of the whole globe; also the weight of the globe's bulk of sea-water is 39.9867 multiplied into 1030 oz. (the weight of a solid foot of sea-water) or 41186.39 oz. av., which, taken from the weight of the whole globe, is 634779·37 oz. av. which is the weight that will just sink the required cork globe below the surface of the water. Then it is plain that every solid foot of cork will take 1030—288. or 792 oz. to sink it. Hence, 792 oz. av. : 1 ft. : : 634779 37 oz. av. : 801.489 solid feet of cork. Lastly, 801·489 solid feet divided by ·5236 (the solidity of a sphere whose diameter is 3) and the cube root extracted, gives 11·523 feet, the diameter of the cork globe required.

This question was also answered by Mr. J. Barr, but by taking the price of standard gold too high, and the specific gravity of sea-water too low, with some other slight mistakes, he makes the value of the gold by far too great, and the diameter of the cork globe considerably too little.

Quest. 39, *answered by* Mr. Whitcombe, *Mathematician, Cornhill.*

Let A C denote the pillar $=$150 feet B C $=$ the height of the statue $=$ 10 feet, and D the required point, then per a fluxionary process (rather too long for the limits of the Artizan) A D is found to be a mean proportional between the distance A B and A C, consequently A D $=$ 154·91, and the A D B $=45^\circ\ 55'\ 55''$, also A D C $=44^\circ\ 4'\ 24''$, : A D B — A D C $=$ B D C $=1^\circ\ 51'\ 31''$ as required.



This question was also answered correctly by Mr. J. Taylor, *Clement's-lane*, and by a correspondent in Bristol, who signs T. D——y; but there must be some mistake in his solution, for he only makes the required angle 52′ 62″, and we know it is 1° 51′ at least.

As this question may be solved geometrically, we will thank some of our mathematical correspondents to send us the construction and demonstration. Ed.

QUESTIONS FOR SOLUTION.

Quest. 43, *proposed by* Mr. J. Whitcombe.

In a given segment of an Elipsis, it is required to inscribe (geometrically) a rectangle, whose length shall be to its breadth as a to c?

Quest. 44, *proposed by* C. G.

Required to divide £20 between A and B, so that the cube of B's share may be £602 less than the cube of A.'s?

PNEUMATICS.

STEAM ENGINE.

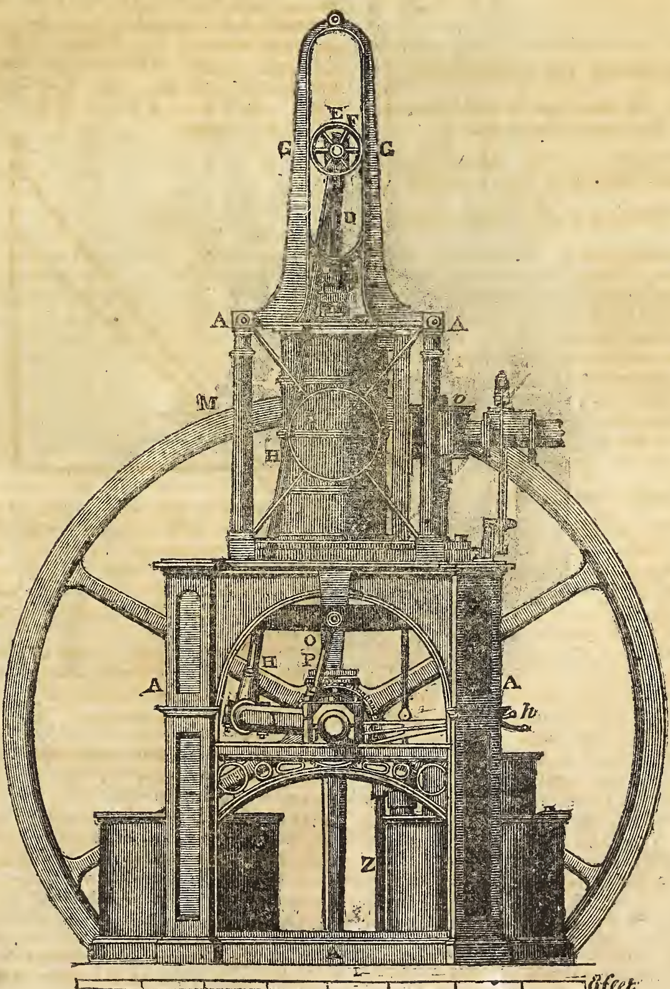
In our last article on Pneumatics, we gave a description and drawing of a newly-invented Gas Engine, which is intended, and will, in all probability, be applied, to perform the same operations as the high pressure steam engines are at present.

Leaving time and experience to decide whether this can be accomplished or not, we shall again resume the subject of the *steam* engine; and in doing this we shall select Mr. Maudslay's *Portable Engine* for the object of our present remarks, because it differs materially, not only from Mr. Watt's, but from all those for which patents have been more recently obtained.

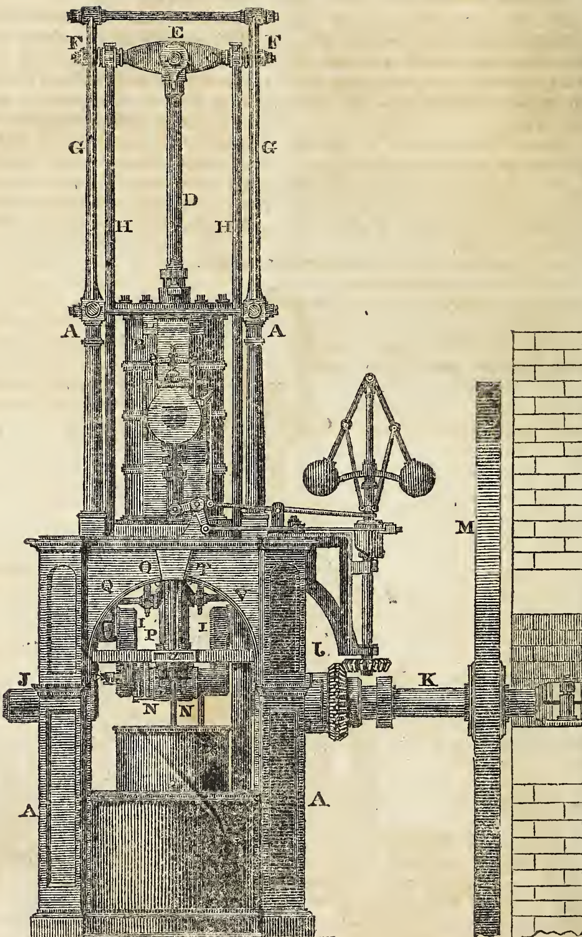
MAUDSLAY'S STEAM ENGINE.

This engine differs from all others, in not having the *beam* usually employed for connecting the fly-wheel crank with the piston rod, in the working of the valves, and in several other respects; but in order to render the construction and operation of this engine more easily understood, we shall give an exact representation of the front elevation, as well as two sections of a ten-horse power engine.

FRONT ELEVATION.



END VIEW.*



A. Is the cast iron frame of the engine.

B. The cylinder.

C. The piston, furnished with the rod D, and a cross head and socket E.

F. Guide wheels, which keep the piston and rod in a vertical position.

G. Frame for ditto, in which the wheels F F are made to work.

H. Side rods, which serve to connect the cross head E with the double crank I I.

I I. Two cranks, made to turn in the plummer-block, or bearing J J at each side of the frame, and to which the fly-wheel shaft K is connected by a coupling-box or clutch, at the end next the engine.

K. Fly-wheel shaft, working in a plummer-block on the wall.

L. Coupling-box, connecting the engine with the fly-wheel shaft.

M. The fly-wheel.

N N. Two eccentric wheels, supported by the crank-shaft K, the action of which give motion to the two beams O and T, by means of the connecting rods P P.

O. The beam which works the cold water pump S.

P P. Two connecting rods.

* The Longitudinal Section will be given in our next.

Q. The double bearing, on which the cold water pump-beam works.

R. A rod which serves to connect the bucket of the cold water pump with the beam O.

S. The barrel of the cold water pump.

T. Beam which works the air and hot water pumps, and to which motion is communicated by the connecting rods P, as before described.

U. The slings which connect the air-pump rod with the end of the beam T.

V. The double bearing or centre, on which the air-pump beam T works.

W. The air-pump bucket.

X. Air-pump cylinder.

Y. Hot water pump, worked by a small rod, attached to the air-pump beam.

Z. Feed-pipe, to supply the boiler with hot water.

a. Cross rail, on which a guide is fixed to confine the air-pump rod in a vertical position.

b. The condenser.

c. The cold water cisterns, connected by a pipe *d*.

e. Eduction pipe, or passage for the steam from the cylinder to the condenser.

f. Injection cock, to admit the cold water into the condenser.

g. Foot valve at the bottom of the air-pump, and communicating from thence to the condenser.

h. Hand gear, for stopping or starting the engine.

i. A rod, connecting the hand gear with an eccentric *k*, fixed on the crank shaft; the action of which communicates a vibratory motion to the rod *i*.

l. Connecting rod, and double ended lever *m*, fixed at the extreme end of a spindle, while a beveled wheel is attached to the other; the latter of which works the spindle of the steam-cone *n*.

o. The steam-cone or cock, for admitting the steam from the boiler to the cylinder; beyond which is a contrivance for shutting off the steam, at the half or any other pat of the stroke, by which a very considerable saving in the steam, and consequently in the fuel, is effected.

OPTICS.

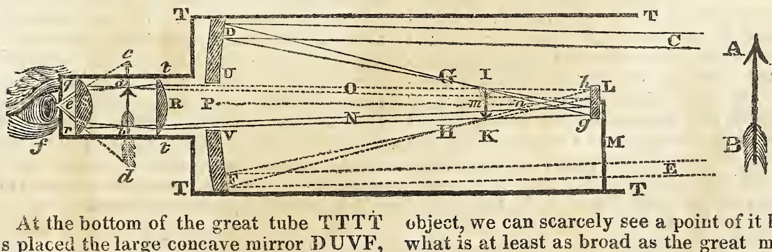
OF THE REFLECTING TELESCOPE.

The great difficulty of managing *refracting* telescopes when of great length, and the impossibility of obtaining a higher magnifying power than 500 times, even by making them 600 feet long, stimulated philosophers to attempt a different mode of constructing telescopes, which they have effected by applying the principle of reflection, instead of that of direct vision. By this means instruments of a much shorter length answer the purpose much better; for a *reflecting* telescope 6 feet long, will magnify as much as a refracting one 100 feet long.

GREGORIAN TELESCOPE.

The first telescope of the reflecting kind, which was found to answer the purpose, was invented by Dr. James Gregory, a Scotsman, about the year 1661.

The instrument which he invented, is represented by the following figure.



At the bottom of the great tube TTTT is placed the large concave mirror DUVF, whose principal focus is at *m*; and in its middle is a round hole P, opposite to which is placed the small mirror L, concave toward the great one; and so fixed to a strong wire M, that it may be moved farther from the great mirror, or nearer to it, by means of a long screw on the outside of the tube, keeping its axis still in the same line P*mn* with that of the great one. Now, since in viewing a very remote object, we can scarcely see a point of it but what is at least as broad as the great mirror, we may consider the rays of each pencil, which flow from every point of the object, to be parallel to each other, and to cover the whole reflecting surface DUVF. But to avoid confusion in the figure, we shall only draw two rays of a pencil flowing from each extremity of the object into the great tube, and trace their progress, through all their reflections and refractions, to the eye *f*, at the end of the small tube *t t*, which is joined to the great one.

Let us then suppose the object A B to be at such a distance, that the rays C may flow from its lower extremity B, and the rays E from its upper extremity A. Then the rays C falling parallel upon the great mirror at D, will be thence reflected converging, in the direction D G; and by crossing at I in the principal focus of the mirror, they will form the upper extremity I of the inverted image I K, similar to the lower extremity B of the object A B: and passing on to the concave mirror L (whose focus is at *n*) they will fall upon it at *g*, and be thence reflected converging, in the direction *g* N, because *g m* is longer than *g n*; and passing through the hole P in the large mirror, they would meet somewhere about *r*, and form the lower extremity *d* of the erect image *a d*, similar to the lower extremity B of the object A B. But by passing through the plano-convex glass R in their way, they form that extremity of the image at *b*. In like manner, the rays E, which come from the top of the object A B, and fall parallel upon the great mirror at F, are thence reflected converging to its focus, where they form the lower extremity K of the inverted image I K, similar to the upper extremity A of the object A B; and thence passing on to the small mirror L, and falling upon it at *h*, they are thence reflected in the converging state *h* O; and going on through the hole P of the great mirror, they will meet somewhere about *q*, and form there the upper extremity *a* of the erect image *a d*, similar to the upper extremity A of the object A B: but by passing through the convex glass R in their way, they meet and cross sooner, as at *a*, where that point of the erect image is formed. The like being understood of all those rays which flow from the intermediate points of the object, between A and B, and enter the tube T T; all the intermediate points of the image between *a* and *b* will be formed: and the rays passing on from the image through the eye-glass S, and through a small hole *e* in the end of the lesser tube *t t*, they enter the eye *f*, which sees the image *a d* (by means of the eye-glass) under the large angle *c e d*, and magnified in length, under that angle from *c* to *d*.

In the best reflecting telescopes, the focus of the small mirror is never coincident with the focus *m* of the great one, where the first image I K is formed, but a little beyond it (with respect to the eye) as at *n*: the consequence of which is, that the rays of the pencils will not be parallel after reflection from the small mirror, but converge so as to meet in points about *q*, *e*, *r*; where they will form a larger upright image than *a d*, if the glass R was not in their way: and this image might be viewed by means of a single eye-glass properly placed between the image and the eye: but then the field of view would be less, and consequently not so pleasant, for which reason, the glass R is still retained, to enlarge the scope or area of the field.

To find the magnifying power of this telescope, multiply the focal distance of the great mirror by the distance of the small mirror from the image next the eye, and multiply the focal distance of the small mirror by the focal distance of the eye-glass: then, divide the product of the former multiplication by the product of the latter, and the quotient will express the magnifying power.

One great advantage of the reflecting telescope is, that it will admit of an eye-glass of a much shorter focal distance than a refracting telescope will; and, consequently, it will magnify so much the more: for the rays are not coloured by reflection from a concave mirror, if it be ground to a true figure, as they are by passing through a convex-glass, let it be ground ever so true.

The adjusting screw on the outside of the great tube fits this telescope to all sorts of eyes, by bringing the small mirror either nearer to the eye, or removing it farther from it: by which means, the rays are made to diverge a little for short-sighted eyes, or to converge for those of a long sight.

The nearer an object is to the telescope, the more its pencils of rays will diverge before they fall upon the great mirror, and therefore they will be the longer of meeting in points after reflection; so that the first image I K will be formed at a greater distance from the large mirror, when the object is near the telescope, than when it is very remote. But as this image must be formed farther from the small mirror than its principal focus *n*, this mirror must be always set at a greater distance from the large one, in viewing near objects, than in viewing remote ones. And this is done by turning the screw on the outside of the tube, until the small mirror be so adjusted, that the object (or rather its image) appear perfect.

CASSEGRAINIAN TELESCOPE.

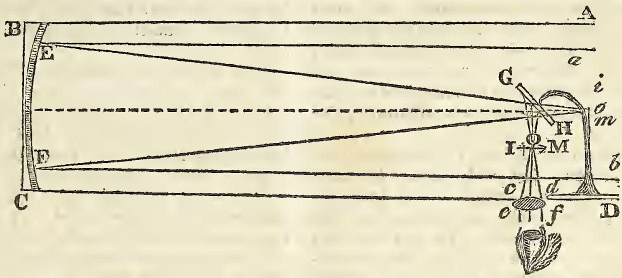
Soon after the discovery of the Gregorian telescope, Mr. Cassegrain, a native of France, produced a reflecting telescope, which he pretended was an original invention; but it differs in no respect from the *Gregorian*, except in having a *convex* instead of a *concave* mirror. This form of the small mirror has the effect of shortening the telescope twice the focal length of the small speculum. But notwithstanding this and some other advantages, which it has in theory over the Gregorian telescope, it is but little used. Captain Kater has, however, made several astronomical observations with it, and found it much superior to a *Gregorian* one of the same magnifying power. This led him to undertake a comparison of the two instruments, for which purpose he caused one of each to be made, having the specula of the same metal, and of the same pattern; their magnifying powers were also nearly the same. He varied the aperture of the Cassegrainian telescope, till he found that both instruments exhibited the letters of a printed card, with equal clearness and distinctness; and after deducting from the exposed area of each, the area of the small speculum and its arm, he found that the reflecting surface of the Cassegrainian was 4·63, while that of the Gregorian was 10·87, making the light of the former, (from equal surfaces) to that of the latter, nearly as *seven* to *three*.

NEWTONIAN TELESCOPE.

The *Newtonian* telescope, which derives its name from its illustrious inventor, Sir I. Newton, can only be considered as an improvement, or rather a variety of the Gregorian telescope, which was described in 1663, in a work called the Optica Promota. But though Newton says he was acquainted with this work, before he invented his reflecting telescope, which was not till after 1664; yet he did not mention the telescope of Gregory, till he was called upon to make some remarks upon that of Cassegrain, who brought it forward as a new discovery, and disputed the invention with him.

In a letter to a friend, dated February 23, 1669, Sir Isaac gives an account of "a small prospective," made to try the truth of his conjecture respecting reflecting telescopes. It was 6¼ inches long, had an aperture about an inch and a third, a plano-convex eye-glass ⅙th or ⅐th of an inch deep, and magnified about 35 times, which he considered as more than could be done by a six feet refracting telescope. With this instrument he saw the horns of Venus and the satellites of Jupiter; but not content with such an experiment, he completed another speculum 2⅛ inches broad, and satisfied himself completely of the superiority of these instruments, which were afterwards brought to such perfection by the labours of Mr. Hadley and the late Sir W. Herschel.

The *Newtonian Telescope* is represented by the following figure.



A B C D is a tube or case; E F a large polished speculum, whose focus is at 0; G H a plane speculum truly concentred, and fixed at half a right angle with the axis of the large one. Then parallel rays, as *a* E, *b* F, falling on the large speculum E F, instead of being reflected to the focus *o*, are intercepted by the small plain speculum G H, and by it reflected towards a hole *c d* in the side of the tube, crossing each other in the point O, which now becomes the true focal point; and from thence they proceed to an eye-glass *e f* placed in that hole, whose focal distance is very small, and therefore the power of magnifying may be very great in this form of the telescope; because the image I M is made by one reflection (for that of the plane speculum only alters the *course* of rays, and adds nothing to the *confusion* of the *image*), and will, for that reason, bear being viewed by a glass of a very deep *charge*, in comparison with an image formed by differently refrangible rays.

In order to obtain a reflection with less loss of light, Sir Isaac Newton proposed to substitute a rectangular prism in place of the small mirror, having its sides perpendicular to the incident and the emerging rays, so that the light might suffer total reflection from its posterior surface. By making these two faces of the prism convex, the object will be seen erect instead of inverted.

As it is more difficult to find any of the celestial bodies with a Newtonian than with a Gregorian telescope, it has been customary to fix a small astronomical telescope on the tube of the former, so that the axis of the two instruments may be parallel.

The aperture of the object-glass is large, and cross hairs are fixed in the focus of the eye-glass. The object is then found by this small telescope, which is called the *finder;* and if the axis of the instruments are rightly adjusted, it will be seen also in the field of the large telescope.

But notwithstanding this contrivance, the Newtonian telescope is not so commodious for common use as the Gregorian, it is therefore very seldom employed either for astronomical or terrestrial observations.

Should any of our readers wish to see a fuller account of this telescope, they may consult Sir I. Newton's Optics, and several papers in the Transactions of the Royal Society, written about the time of its construction.

CHEMISTRY.

IODINE.

Iodine was accidentally discovered in 1812, by M. de Courtois, a manufacturer of saltpetre at Paris. In his processes for procuring soda from the ashes of sea weeds, he found the metallic vessels much corroded; and in searching for the cause of the corrosion, he made this important discovery. But for this circumstance, merely accidental, one of the most curious of substances might have remained for ages unknown, since Nature has not distributed it, in either a *simple* or *compound* state, through her different kingdoms, but has confined it, to what the Roman satirist considers as the most worthless of things, the *vile sea weed.*

Iodine derived its first illustration from M. M. Clement and Desormes. In their memoir, read at a meeting of the Institute of France, these able chemists described its principal properties. They stated its specific gravity to be about 4; that it becomes a *violet coloured gas* at a temperature below that of boiling water, whence it received the name of *Iodine*, which is a word derived from the Greek, signifying, *like a violet;* that it combines with the metals, and with phosphorus, and sulphur, and likewise with the alkalis and metallic oxides; that it forms a detonating compound with ammonia; that it is soluble in alcohol, and still more soluble in ether; and that by its action upon phosphorus and upon hydrogen, a substance is formed, having the characters of muriatic acid. In this communication they offered no decided opinion respecting its nature.

In 1813 Sir H. Davy happened to be on a visit to Paris, and when M. Clement shewed him Iodine, he said that he believed it was a substance analogus in its chemical relations to chlorine.

Iodine has been found in various kinds of sea weed. But it is from the incinerated sea weed or kelp, that Iodine is to be obtained in quantities. Dr. Wollaston first communicated a precise formula for extracting it, which is as follows: Dissolve the soluble part of kelp in water; concentrate the liquid by evaporation, and separate all the crystals that can be obtained. Pour the remaining liquid into a clean vessel, and mix with it an excess of sulphuric acid. Boil this liquid for some time. Sulphur is precipitated, and muriatic acid driven off. Decant off the clear liquid, and strain it through wool. Put it into a small flask, and mix it with as much black oxide of manganese, as was used before of sulphuric acid. Apply to the top of the flask a glass tube, shut at one end. Then heat the mixture in the flask. The Iodine sublimes into the glass tube. None can be obtained from sea water.

In repeating this process, Dr. Ure, of Glasgow, obtained from similar quantities of kelp such variable products of Iodine, that he was induced to institute a series of experiments for discovering the causes of these anomalies, and for procuring Iodine at an easier rate. In this he appears to have been successful, for instead of procuring this singular element in such small quantity as a few grains, he has obtained ounces at a time, and at a moderate expense. But our limits will not permit us to give a detail of the process he pursued.*

The substance he obtained it from was the residuum of soap leys, the alkaline matter of which consisted solely of kelp. From this residuum he first obtained a brown oily liquid, and from this liquid he procured Iodine in considerable quantity.

Iodine is a solid, of a greyish-black colour and metallic lustre. It is often in scales similar to those of micaceous iron ore, semetimes in rhomboidal plates, very large and very brilliant. It has been obtained in elongated octahedrons, nearly half an inch in length; the axis of which were shown by Dr. Wollaston to be to each other, as the numbers 2, 3, and 4, at least so nearly, that in a body so volatile, it is scarcely possible to detail an error in this estimate, by the reflective goniometer. Its fracture is lamellated, and it is soft and friable to the touch. Its taste is very acrid, though it is very sparingly soluble in water. It is a deadly poison. It gives a deep brown stain to the skin, which soon vanishes by evaporation. In odour, and power of destroying vegetable colours, it resembles very dilute aqueous chlorine. The specific gravity of Iodine at $62\frac{1}{2}^{\circ}$ is 4·948. It dissolves in 7000 parts of water.

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* This will be found in the 50th vol. of the Philosophical Magazine.

The solution is of an orange yellow colour, and in small quantity tinges raw starch of a purple hue, which vanishes on heating it. It melts, according to M. Gay Lussac, at 227° F., and is volatilized under the common pressure of the atmosphere, at the temperature of 350°. According to Ure, it evaporates pretty quickly at ordinary temperatures. Boiling water aids its sublimation, as is shown in the above process of extraction. The specific gravity of its violet vapour is ·8678. It is a non-conductor of electricity. When the voltaic chain is interrupted by a small fragment of it, the decomposition of water instantly ceases.

Iodine is incombustible, but with azote it forms a curious detonating compound; and in combining with several bodies, the intensity of their mutual action is such, as to produce the phenomena of combustion.

Iodine combines with oxygen and with chlorine; but these combinations will be described when treating of iodic acid.

With a view of determining whether it was a simple or compound form of matter, Sir H. Davy exposed it to the action of the highly inflammable metals. When its vapour is passed over potassium heated in a glass tube, inflammation takes place, and the potassium burns slowly with a pale blue light. There was no gas disengaged when the experiment was repeated in a mercurial apparatus. The iodide of potassium is white, fusible at a red-heat, and soluble in water. It has a peculiar acrid taste.* When acted on by sulphuric acid, it effervesces, and iodine appears. It is evident, that in this experiment there had been no decomposition; the result depending merely on the combination of iodine with potassium. By passing the vapour of iodine over dry red hot potash, formed from potassium, oxygen is expelled, and the above iodide results. Hence we see, that at the temperature of ignition, the affinity between iodine and potassium, is superior to that of the latter for oxygen. But iodine in its turn is displaced by chlorine, at a moderate heat; and if the latter be in excess, chloriodic acid is formed. M. Gay Lussac passed vapour of iodine in a red heat over melted sub-carbonate of potash; and he obtained carbonic acid and oxygen gases, in the proportions of two in volume of the first, and one of the second, precisely those which exist in the salt

The oxide of sodium, and the sub-carbonate of soda, are completely decomposed by iodine. From these experiments it would seem, that this substance ought to disengage oxygen, from most of the oxides; but this happens only in a small number of cases. The protoxides of lead and bismuth are the only oxides not reducible by mere heat, with which it exhibited that power.* Barytes, strontian, and lime, combine with iodine, without giving out oxygen gas, and the oxides of zinc and iron undergo no alteration in this respect. From these facts we must conclude, that the decomposition of the oxides by iodine depends less on the condensed state of the oxygen, than upon the affinity of the metal for iodine. Except barytes, strontian, and lime, no oxide can remain in combination with iodine at a red heat.

M. Gay Lussac says, "Sulphate of potash was not altered by iodine; but what may appear astonishing, I obtained oxygen with the fluate of potash, and the glass tube in which the operation was conducted was corroded. On examining the circumstances of the experiment, I ascertained that the fluate became alkaline when melted in a platinum crucible. This happened to the fluate over which I passed iodine. It appears then that the iodine acts upon the excess of alkali, and decomposes it. The heat produced disengages a new portion of fluoric acid or its radical, which corrodes the glass; and thus by degrees the fluate is entirely decomposed." These facts seem to give countenance to the opinion, that the fluoric is an oxygenized acid; and that the salt called fluate of potash is not a fluoride of potassium.

Iodine forms with sulphur a feeble compound of a greyish-black colour, radiated like sulphuret of antimony. When it is distilled with water iodine separates.

Iodine and phosphorus combine with great rapidity at common temperatures, producing heat without light. From the presence of a little moisture, small quantities of hydriodic acid gas are exhaled.

Oxygen expels iodine from both sulphur and phosphorus. "Hydrogen," says Gay Lussac, "whether dry or moist, did not seem to have any action on iodine at the ordinary temperature of the atmosphere; but if, as was done by Clement, in an experiment in which I was present, we expose a mixture of hydrogen and iodine to a red heat in a tube, they unite together, and hydriodic acid is produced, which gives a reddish-brown colour to water." Sir H. Davy, with his characteristic ingenuity, threw the violet coloured gas upon the flame of hydrogen, when it seemed to support its combustion. He also formed a compound of iodine with hydrogen, by

* When iodine is combined with any other substance, the compound is called an *iodide* of that substance.

† A protoxide signifies a substance combined with one, or the first, dose of oxygen.

heating to redness the two bodies in a glass tube.

Charcoal has no action upon iodine, either at a high or low temperature. Several of the common metals, on the contrary, as zinc, iron, tin, mercury, attack it readily, even at a low temperature, provided they be in a divided state. Though these combinations take place rapidly, they produce but little heat, and but rarely any light.

When iodine and oxides act upon each other in contact with water, the water is decomposed; its hydrogen unites with iodine, to form hydriodic acid; while its oxygen, on the other hand, produces with iodine, iodic acid. All the oxides, however, do not give the same results. We obtain them only with potash, soda, barytes, strontian, lime, and magnesia.

From all the above recited facts, we are warranted in concluding iodine to be *an undecompounded body*. In its specific gravity, lustre, and magnitude, it resembles the metals; but in all its chemical agencies, it is analogous to oxygen and chlorine. It is a non-conductor of electricity, and possesses, like these two bodies, the negative electrical energy with regard to metals, inflammable, and alkaline substances; and hence, when combined with these substances in aqueous solution, and electrized in the voltaic circuit, it seperates at the positive surface. But it has a positive energy with respect to chlorine; for when united to chlorine, in the chloriodic acid, it separates at the negative surface. This likewise corresponds with their relative attractive energy, since chlorine expels iodine from all its combinations. Iodine dissolves in carburet of sulphur, giving, in very minute quantities, a fine amethystine tint to the liquid.

Iodide of mercury has been proposed for a pigment;* in other respects, iodine has not been applied to any purpose of common life. M. Orfila swallowed 6 grains of iodine; and was immediately affected with heat, constriction of the throat, nausea, eructation, salivation, and cardialgia. In ten minutes he had copious bilious vomitings, and slight colic pains. His pulse rose from 70 to about 90 beats in the minute. By swallowing large quantities of mucilage, and emollient clysters, he recovered, and felt nothing next day but slight fatigue. About 70 or 80 grains proved a fatal dose to dogs. They usually died on the fourth or fifth day.

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* There are two iodides of mercury, the one yellow and the other red; both are fusible and volatile.

ASTRONOMY.

OF THE FIXED STARS.

The fixed stars are considered by Astronomers as forming no part of the solar system; but as placed far beyond the utmost limits of it. They have supposed, that each star is a sun, having a number of planets and comets circulating round it; and that each of the planets, thus circulating round these luminaries, may be a habitable world like our own.

The strongest argument for this hypothesis is, that fixed stars cannot be magnified by the most powerful telescopes, on account of their extreme distance. Hence it is concluded, that they shine by their *own* light; and that each of them is a sun equal, if not superior, in lustre and magnitude to our own.

When the stars are examined through a telescope, they rather seem diminished than increased in size. This circumstance alone would have been a striking proof of the immeasurable distance of these bodies, had we not been in possession of still more convincing evidence. In every attempt which Astronomers have made with the best of instruments, to discover the *parallax* of the stars, they never found it to amount to *one* second, even when the earth was in opposite points of her orbit; and therefore they have determined that the nearest of these luminaries cannot be less than 206,265 times the radius of the earth's orbit. As light traverses the latter in 8′ 13″, it will require 3 years and 79 days to come from a fixed star to the earth. And it is believed some of them may be so remote, that their light has not yet reached the earth since they were created;—while others, which have disappeared, or have been destroyed many ages ago, may continue to shine in the heavens, till the last ray, which they emitted, has reached our globe.

The number of stars discoverable at any time in the heavens, by the naked eye, is not above a thousand. This may at first appear incredible to some, because they seem to be innumerable; but the deception arises from looking upon them hastily, without reducing them into any kind of order. For let any person look steadily a little time upon a large portion of the heavens, and count the number of the stars in it, and he will be surprised to find the number so small. And if the moon be observed for a short space of time, she will be found to meet with very few in her way, although there are as many about her path as in any other part of the heavens.

Flamstead's catalogue of the stars in both hemispheres, contains only 3000; and a great number of these cannot be seen without the assistance of a telescope. When the heavens are examined with a good telescope, the stars are not found to be uniformly scattered over the firmament. In some places they are crowded together; and, in other parts, there are large spaces where no stars can be seen. Besides these starry groups, where the individual stars are distinctly visible, there are numbers of small luminous spots, of a cloudy appearance, called *Nebulæ*. The largest of these nebulæ is the galaxy or milky way, a white luminous zone, which nearly encircles the heavens; and which appears to be the nearest of all the nebulæ.

While the heavens exhibit these appearances, which may be termed *constant*, they occasionally exhibit others of a different kind, which seem to arise from some great physical changes that are going on in the universe. Several new stars have appeared for a time, and then vanished; some that are inserted in the ancient catalogues can no longer be found, while others are constantly and distinctly visible, which have not been described by any of the ancients. Some have gradually increased in lustre; others have been gradually diminishing, and a great number sustain a *periodical* variation in their brilliancy.

In order to explain these singular changes, Astronomers have supposed that the stars are suns, having part of their surface occupied by large black spots, which, in the course of their rotation about an axis, present themselves to us, and thus diminish the brilliancy of the star. Some Astronomers suppose the black spots to be permament; but others are of opinion that the luminious surface of these bodies is subject to perpetual change, which sometimes increase their light, and at others extinguish it.

The stars are divided into orders or classes, according to their apparent magnitudes. Those that appear largest to the naked eye have been called stars of the first magnitude; those that appear next largest the second magnitude, and so on, to the sixth, which comprehends the smallest stars that are visible to the naked eye. All those that can only be perceived by the help of a telescope, are called telescopic stars.

The stars of each class are not all of the *same* apparent magnitude. In the first class, or those of the first magnitude, there are scarcely two that appear of the same size.

There are also other stars, of intermediate magnitudes, which astronomers cannot refer to any particular class, and therefore they place them between two; but on this subject Astronomers differ considerably; some of them classing a star among those of the first magnitude, while others class it among those of the second, and so on with others.

In fact it may be said, that there are almost as many orders of stars as there are stars, on account of the great variations observable in their magnitude, colour, brightness, &c. Whether these varieties of appearance are owing to a diversity in their real magnitudes, or from their different distances, it is impossible to determine; but it is highly probable that both of these causes contribute to produce these effects.

To the naked eye the stars appear of a sensible magnitude, owing to the glare of light arising from the numberless reflections from the ærial particles, &c. about the eye; this makes us imagine the stars to be much larger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter our eyes without being intermixed with others. Any person may be sensible of this, by looking at a star of the first magnitude through a long narrow tube, which, though it takes in as much of the heavens as would hold a thousand such stars, it scarcely renders that one visible. The stars being so immensely distant from the earth, there seems to be but little probability of ascertaining with certainty, the real magnitude of any of them.

And as the late Sir W. Herschel has very justly remarked, "that in the classification of stars into magnitudes, there is either no natural standard, or at least none that can be satisfactory; and that the Astronomers who have thus classed them, have referred their size or lustre to some imaginary standard."

The same illustrious Astronomer observes, "That the inconvenience arising from this unknown, or at least ill-ascertained standard, to which we are to refer is such, that all our most careful observations labour under the greatest disadvantage. If any dependance could be placed on the method of magnitudes, it would follow that many of the stars had undergone a change in their lustre, or apparent magnitude even since the time of Dr. Flamstead. Not less than eleven stars in the constellation Leo have undergone a change of lustre since his time." This change Sir W. Hershel believes has arisen from the uncertainty of the standard of magnitudes, and not from any real change in the lustre of stars: and in order to prevent mistakes of this nature to future observers, Sir William proposes to compare the lustre of any particular star with one that is greater, and also with one that is less, both of which are to be as near the proposed star as possible. This he thinks would answer much better for detecting a change in the lustre of any suspected star, than the vague method of magnitudes, which has been hitherto in use among Astronomers.

As a full display of Sir W.'s method would occupy more space than can be allotted to it in this work, those who wish to have more information on the subject, may consult the Philosophical Transactions, vol. 86,—or a popular work on Astronomy, now publishing by the publishers of this work.

The variation in the light of the stars has been ascribed to the interposition of the *planets* that revolve round them; but it is not probable that the planets are sufficiently large, to produce any sensible effect of this kind, at least.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF NICOLAS SAUNDERSON, L. L. D.

Nicolas Saunderson, an illustrious Professor of the Mathematics in the University of Cambridge, and Fellow of the Royal Society, was born in 1682, at Thurlston in Yorkshire; where his father, besides a small estate, enjoyed a place in the excise. When he was a year old, he was deprived by the small-pox, not only of his *sight*, but of his *eye-balls*, which were dissolved by abscesses, so that he retained no more idea of light and colours, than if he had been *born* blind. He was sent early to a free-school at Penniston, and there laid the foundation of that knowledge of the Greek and Roman languages, which he afterwards improved so far, by his own application to the classic authors, as to hear the works of Euclid, Archimedes, and Diophantus, read in their original Greek. When he had passed some time at this school, his father, whose occupation led him to be conversant in numbers, began to instruct him in the common rules of arithmetic. Here it was that his genius first appeared; for he very soon became able to work the common questions, to make long calculations by the strength of his memory, and to form new rules to himself for the more ready solving of such problems as are often proposed to learners as trials of skill. At eighteen, he was introduced to the acquaintance of Richard West, of Underbank, Esq. a gentleman of fortune, and a lover of the mathematics, who, observing his uncommon capacity, took the pains to instruct him in the principles of Algebra and Geometry, and gave him every encouragement in the prosecution of those studies. Soon after, he became acquainted with Dr. Nettleton, who took the same pains with him; and it was to these gentlemen that he owed his elementary knowledge of the mathematical sciences. They furnished him with books, and often read and expounded them to him; but he soon surpassed his masters, and became fitter to teach them than to learn any thing from them. His passion for learning growing up with him, his father sent him to a private academy at Atlercliff, near Sheffield. But Logic and Metaphysics being the principal learning of this school, were neither of them agreeable to the genius of our author; and therefore he made but a short stay. He remained some time after in the country, prosecuting his studies in his *own way*, without any other assistant than a good author, and some person that could read it to him: being able, by the strength of his own abilities, to surmount all difficulties that might occur. His education had hitherto been at the expense of his father, who, having a numerous family, found it difficult to continue it; and his friends therefore began to think of fixing him in some way of business, by which he might support himself. His own inclination led him strongly to Cambridge; and after much consideration, it was resolved he should make his appearance there in a way very uncommon; not as a *scholar*, but a *master;* for his friends, observing in him a peculiar felicity in conveying his ideas to others, hoped that he might teach the Mathematics with credit and advantage, even in the *University;* or, if this design should miscarry, they promised themselves success in opening a school for him in London.

Accordingly, in 1707, being now twenty-five, he was brought to Cambridge by Mr. Joshua Dunn, then a fellow-commoner of Christ's College; where he resided with that friend, but was not admitted a member of the college. The society, however, much pleased with so extraordinary a guest, allotted him a chamber, the use of their library, and indulged him in every privilege that could be of advantage to him. But still many difficulties obstructed his design: he was placed here without friends, without fortune, a young man, untaught himself, to be a teacher of philosophy in a university, where it then flourished in the greatest perfection. Whiston was at this time Mathematical Professor, and read lectures in the manner proposed by Saunderson, so that an attempt of the same kind by the latter, looked like an encroachment on the privileges of his office; but, as a good-natured man, and an encourager of learning, Whiston readily consented to the application of friends, made in behalf of so uncommon a person. Mr. Dunn had been very assiduous in making known his character; his fame in a short time had filled the university; men of learning and curiosity grew ambitious and fond of his acquaintance, so that his lecture, as soon as opened, was frequented by many, and in a short time very much crowded. "The *Principia Mathematica*, *Optics*, and *Arithmetica Universalis*, of Sir Isaac Newton," were the foundation of his lecture; and they afforded a noble field for displaying his genius. It was indeed an object of the greatest curiosity to hear a blind youth read lectures in optics, discourse on the nature of *light* and *colours*, explain the theory of vision, the effect of glasses, the phænomena of the rainbow, and other objects of sight; nor was the surprise of his auditors much lessened by reflecting, that as this science is altogether to be explained by lines, and is subject to the rules of geometry, he should be master of these subjects, even under the loss of sight.

As he was instructing the academical youth in the principles of the Newtonian philosophy, it was not long before he became acquainted with the incomparable author, although he had left the university several years; and enjoyed his frequent conversation concerning the more difficult parts of his works. He lived in friendship also with the most eminent mathematicians of the age; with Halley, Cotes, De Moivre. Upon the removal of Whiston from his professorship, Saunderson's mathematical merit was universally allowed to be so much superior to that of any other competitor, that an extraordinary step was taken in his favour, to qualify him with a degree, which the statutes require. Upon application made by the heads of colleges to the Duke of Somerset, their chancellor, a mandate was readily granted by the queen for conferring on him the degree of Master of Arts: upon which he was chosen Lucasian Professor of the Mathematics, Nov. 1711, Sir Isaac Newton all the while interesting himself very much in the affair. His first performance after he was seated in the chair, was an inaugural speech made in very elegant Latin, and a style truly Ciceronian; for he was well versed in the writings of Tully, who was his favourite in prose, as Virgil and Horace were in verse. From this time he applied himself closely to the reading of lectures, and gave up his whole time to his pupils. He continued among the gentlemen of Christ's College till 1723; when he took a house in Cambridge, and soon after married a daughter of the Rev. Mr. Dickens, Rector of Boxworth, in Cambridgeshire, by whom he had a son and a daughter. In 1728, when George II. visited the university, he was pleased to signify his desire of seeing so remarkable a person; and accordingly the professor waited upon his majesty in the Senate-house, and was there created Doctor of Laws by royal favour.

Saunderson was naturally of a strong healthy constitution, but being too sedentary, and constantly confining himself to the house, he became at length a valetudinarian. For some years he frequently complained of a numbness in his limbs, which in the spring of 1739, ended in an incurable mortification of his foot. He died April 19, aged fifty-seven, and was buried according to his request, in the chancel at Boxworth. He had much wit and vivacity in conversation, and many reckoned him a good companion. He had also a great regard to truth, but was one of those who think it their duty to express their sentiments on men and opinions, without reserve or restraint, or any of the courtesies of conversation, which created him many enemies, and by the obtrusion of infidel opinions, which last he held throughout his extraordinary life.* He is said, however, to have received the notice of his approaching death with great calmness and serenity; and after a short silence, resuming life and spirit, talked with as much composure as he usually did when in perfect health.

A blind man moving in the sphere of a *mathematician*, seems a phænomenon difficult to be accounted for, and has excited the admiration of every age in which it has appeared. Tully mentions it as a thing scarcely credible in his own master in philosophy, Diodotus, that "he exercised himself in that science with more assiduity after he became blind, and, what he thought almost impossible to be done without sight, that he described his geometrical diagrams so accurately to his scholars, that they could draw every line in its proper direction." Jerome relates a more remarkable instance in Didymus of Alexandria, who, "though blind from his infancy, and therefore ignorant of the very letters, appeared so great a miracle to the world, as not only to learn logic, but geometry also, to perfection, which seems the most of any thing to require the help of sight." But, if we consider that the ideas of extended quantity, which are the chief objects of mathematics, may as well be acquired from the sense of feeling, as that of sight; that a fixed and steady attention is the principal qualification for this study, and that the blind are by necessity more abstracted than others, for which reason Democritus is said to have put out his eyes, that he might think more intensely.

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* "With respect to the infidel part of Saunderson's character," says the Monthly Reviewer, "we are here naturally reminded of the joke that was passed on the learned university, on his being elected to fill the Lucasian chair—they have turned *out Whiston* for believing in but *one God*, and they have put *in* Saunderson, who believes in *no God* at all."—Monthly Review, vol. 36.

An exact and refined ear is what such are commonly blessed with who are deprived of their eyes; and Saunderson was perhaps inferior to *none* in the excellence of his. He could readily distinguish to the fifth part of a note; and, by his performance on the flute, which he had learned as an amusement in his younger years, discovered such a genius for music, as, if he had cultivated the art, would have probably appeared as wonderful as his skill in the mathematics. By his quickness in the sense of hearing, he distinguished persons with whom he had only once conversed. He could judge of the size of a room, into which he was introduced, of the distance he was from the wall; and if ever he had walked over a pavement in courts, piazzas, &c. which reflected a sound, and was afterwards conducted thither again, he could exactly tell whereabouts in the walk he was placed, merely by the note it sounded.

There was scarcely any part of the mathematics on which he had not written something for the use of his pupils: but he discovered no intention of publishing any of his works till 1733. Then his friends, alarmed by a violent fever that had threatened his life, and unwilling that his labours should be lost to the world, importuned him to spare some time from his lectures, and to employ it in finishing some of his works; which he might leave behind him, as a valuable legacy both to his family and the public. He yielded so far to these entreaties, as to compose in a short time his "Elements of Algebra;" which he left perfect, and transcribed fair for the press. It was published by subscription at Cambridge, 1740, in 2 vols. 4to. with a good mezzotinto print of the author, and an account of his life and character prefixed.

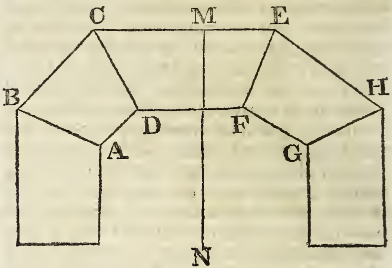
The mode by which Saunderson performed his calculations, was by a species of palpable arithmetic; that is, a method of performing operations in arithmetic, solely by the sense of *touch*. The apparatus he employed, consisted of a table raised upon a small frame, so that he could apply his hands with equal ease both above and below it. On this table were drawn a great number of parallel lines which were crossed by others at right angles; the edges of the table were divided by notches half an inch distant from one another, and between each notch there were five parallels; so that every square inch was divided into a hundred little squares. At each angle of the squares where the parallels intersected one another, a hole was made quite through the table. In each hole he placed two pins, a large and a small one. It was by the various arrangements of the pins, that Saunderson performed all his operations.

ARCHITECTURE.

ON THE CONSTRUCTION OF ARCHES.

As we have now given a short account of the five Orders, and also pointed out the peculiarities of Gothic Architecture, we shall here endeavour to explain the particular parts and properties of arches and bridges.

A series of truncated wedges resting on two immoveable supports, and having the planes of the faces that press against each other, perpendicular to a vertical plane (represented by the plane of the paper), as in the following figure, form what are called *arches* in Architecture.



The most advantageous construction of arches, requires that the parts should be so adjusted as to be in *equilibrio*, or to balance one another by their weight only; when this is the case, the arch is called an *arch of equilibration.*

Some other definitions are necessary for understanding the construction of these arches. The truncated wedges of which the arch is composed, and which are usually of stone, are called the voussoirs; each course of these wedges forming one voussoir. The central voussoir is called the key-stone. The surfaces which seperate the voussoirs from one another, are called the joints. The interior curve of the arch is called the *intrados;* the exterior, or that which limits all the voussoirs, when they are in equilibrium, is called the *extrados.* The abutments are masses of masonry, at each end, that support the arch. The beginning of the arch is called the spring of the arch; the middle, the crown; the parts between the spring and the crown, the haunches. The part of the abutment from which the arch springs, is termed the impost.

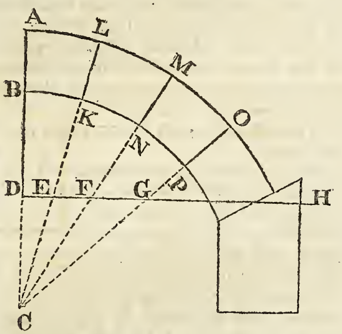
If the weights of the *voussoirs* be to each other, as the difference of the *tangents* which A B, D C, E F, &c. make with the verticle M N (see the foregoing figure), the whole will be in equilibrio. This follows from the properties of the wedge. See page 148.

This theorem is sufficient for the construction of arches of any form, because when the curve of the *intrados* is given, it determines the weight of every individual voussoir. The application of it in particular cases, admits, however, of being greatly simplified.

A remarkable instance of this happens when the arch is a circle, and when the joints, (which are usually made perpendicular to the curve of the intrados) intersect in the same point.

In a *circular arch*, the weights of the voussoirs should be as the differences of the tangents of the arches, reckoned from the *crown*.

This is nothing more than the above proposition, applied to a particular case. Thus in the following figure:



If B be the crown of a circular arch, the weight of the voussoir L K N M should be to that of the voussoir M N P O, as the tangent of B N, *minus* the tangent of B K, to the tangent of B P, *minus* the tangent of B N; or if, from a given point D, D H be drawn perpendicular to A C; and if the joints K L, &c. be produced, to cut in E, F, and G, the weights of the voussoirs must be as the segments D E, E F, F G, in order to produce an equilibrium.

As the stones themselves cannot always be made in the proportion thus required, the wedges, of which they make parts, are supposed to be extended upward by courses of masonry. The whole mass included between the plane of the joints produced, as far as that masonry extends, is understood to make up the weight of the voussoir. It is the business of the theory to calculate this weight; and construct the curve which bounds the voussoirs, when so produced.

To the Editor of the Artisan.

Sir,

Impelled by the dictates of humanity, and perceiving that a miscellaneous part always forms a portion of each number of your valuable scientific work, I am induced to request a place in it on a subject of particular interest to those who are obliged to navigate the seas in the coasting trade during the stormy months of Winter, and also to many humane individuals residing on the coast, who at that boisterous season have been so often called upon to witness the dreadful effects of a "Winter's Gale," when

"Again the dismal prospect opens round,
The wreck, the shore, the dying, and the drown'd.'

It is not my intention to attempt a description of what must be the feelings of those, who are in many cases obliged to be helpless spectators of such distressing scenes; but by pointing out the means of assistance, which, though long since partially known, has been too much generally neglected, I hope to enable them to exchange their hitherto melancholy feelings on such occasions, for those of joy as indescribable, when they shall have rescued their fellow-creatures from a watery grave, instead of being constrained to witness their premature destruction.

In the year 1791, Mr. John Bell, a Serjeant of Artillery, made several experiments before a committee of the Society of Arts, at Woolwich, wherein he plainly proved the practicability of throwing a rope from a mortar over a stranded vessel; by which means such a communication might be established between the people on shore, and the wreck, as would enable the former to save the lives of the crew.

The following is a figure and brief description of Mr. Bell's apparatus.

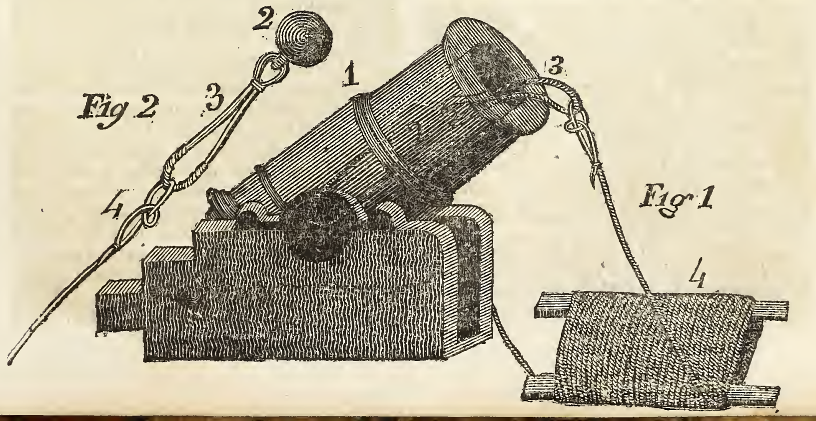


Fig. 1, represents an 8-inch mortar on its carriage, the chamber of which being constructed to contain only one pound of powder, effectually secures it from bursting—2. A cast-iron shell filled with lead, which weighed 75 lbs—3. The grommet, or double rope, which was white three-inch; this connected the shell and line—4. The line wound round poles or handspikes, which were withdrawn when the mortar was fired.—A reel has lately been invented as a substitute for the handspikes: but if the line is coiled in a ziz-zag direction before, and on one side of the mortar, it will be found to go out more freely than in any other way. The rope first tried by Mr. Bell, was a deep-sea line, of which 160 yards weighed 18 lbs: this line with the shell was thrown 400 yards from the mortar, at the elevation of 45°, with a charge of only 15 oz. of powder.

Fig. 2 is a seperate view of the shell, with the grommet and end of the line attached thereto, explained by the same figures.

This excellent invention, which, as Mr. Bell observes, is so exceedingly simple, that any person once seeing it done, would want no farther instructions, I trust, through the medium of your widely circulating work, will become more generally known and practised upon the coast; for as it is the exclusive attribute of the Almighty to give life, the most exalted act of man must be to save the life of his fellow man.

Should a farther description be required, I beg leave to refer you and your numerous readers to the 10 vol. of the Trans. Soc. Arts, and 20th vol. of Nicholson's Phil. Journal, from which I have made this abridgment, for the benefit of those who may not be able to consult these expensive works. I am, Sir,

Your obedient humble servant,

NAVARCHUS.

ON THE METHOD OF WARMING APARTMENTS BY HEATED AIR.

In place of an expensive apparatus, which is attainable by the rich alone, M. Meissner has given us a method, which is equally adapted to the use of a palace or a cottage; costing little, and presenting every advantage possessed by the most expensive, at the same time that its use is unattended by their inconveniences; contributing very much towards the salubrity of the air in houses, and is at the same time proof against fire.

In a small room called the stove-room, and where he places a stove (either of iron or earthenware) Mr. Meissner conducts, by means of sheet iron pipes, a current of heated air, into those apartments which he would warm; at the same time that a current of cold air is forced back into the chamber of heat, from the room where the heated air has found admission, thus establishing a circulation which includes the whole mass of air in the room, the temperature of which is desired to be encreased; and which does not cease until there no longer exists any difference in the temperature of the different strata of air, which are in communication with the stove apparatus. To produce this effect, the current of heated air being specifically the lightest, must necessarily pass through pipes which are placed high in the walls of the stove-room, near the ceiling, and flows at different heights into the room to be heated; on the other hand the cold air being specifically the densest, will flow through corresponding pipes fixed low down in the wall of the rooms to be heated from other pipes, placed at the same part in the walls of the stove-room.

The apparatus may be constructed either on the ground floor or in the cellar; it may also be placed in a corner of a kitchen or in a chimney, which has a general communication with the chimneys of the house; in this case, the communication between the rooms and the apparatus may be formed by simply making holes in the chimney-walls of each room; in the former by means of the pipes. These holes and the pipes likewise, must each be furnished with dampers with which to increase, diminish, or exclude altogether the currents of air to or from the stove-room at the will of its occupants.

But, that each room must necessarily be furnished with a double communication with the stove-room will be sufficiently understood, when the above description is carefully perused.

When a change of air is requisite, there is a communication between the outward air and each room, and also one between the outward air and the stove-room, furnished likewise with the same means of diminishing or excluding its admission; thus enabling the rooms to be thoroughly aired without opening the doors or windows.

It is to Mr. Meissner, also, that we owe an apparatus which he designates a mantle; to be used in case only one apartment is required to be heated. The stove is enclosed in a sort of envelope (formed of potters' earth) and of its exact form. The intermediate space between this covering and the stove is necessarily filled with air, and in this way the whole may be carried into the room where the heat is required. The upper orifices of the envelope represent the highest pipes of the stove-room; and the lower ones, the lower pipes. The instant the temperature of the air in the intermediate space is heightened, it flows through the upper orifices and is immediately succeeded by the cold air flowing through the lower orifices, thus exhibiting in miniature the action of the stove-room.

Of the advantages to be derived from the use of this apparatus it is almost unnecessary to speak. Economy in fuel, prevention of any accidents by fire: should it be constructed in the kitchen, a great baving in coals will take place; and it will be much easier to take care of one fire than of several.

METHOD OF POUNCING UPON CLOTH, THE DESIGNS WITH WHICH THEY ARE TO BE EMBROIDERED.

The ordinary means employed in this art, are as follows. Having pricked any design upon paper with a needle, it is dusted over with a piece of muslin containing charcoal very finely pounded and sifted, the dust gets through the holes pricked on the design, and settles on the cloth which is to be embroidered; then with a black or white pencil, according to the colour of the cloth, the marks left by the charcoal-dust are exactly to be followed.

The person who does this ought either to possess a knowledge of drawing, or else to have much adroitness, in order that the form of the design may be exactly preserved; but often before the pattern can be finished the dust flies off, and thus occasions much embarrassment to the workers. Messrs. Revol and Rigoudet perceiving all the difficulties which attend this method of proceeding, have sought for, and at length ingeniously contrived a remedy; and the patent which they obtained for their invention having expired, we shall proceed to describe the means they employ.

Previously to this process no means of fixing the dust upon the cloth had ever been ascertained, and every person who was employed in this work was obliged to trace with a pen or pencil the design formed by the dust, which not only occupied a great part of their time, but often occasioned mistakes in the figure to be embroidered. The new method possesses the advantages of being able to convey to the cloth the exact figure of the design, and facilitates the progress of the embroiderers, allowing them to attain the greatest exactitude in their work, and sparing them the trouble and time they had employed in retracing the design.

The method of preparing the composition of the powder for pouncing in black, is as follows:

Place an *earthen* pot over the fire, and put into it a given quantity of gum mastic, adding thereto one-thirtieth part of wax, oil, tar, or pitch; when this is melted, throw into the pot as much lampblack as may be deemed necessary for the colour of the pounce, stirring the mixture all the time with an iron spoon. When all is well mixed, take it from the fire and pour it into sheets of paper, with the corners turned up to prevent its running over, and, when well cooled, pound and sift it, and enclose it in a piece of muslin. Pounce with this whatever design it is intended to form upon any kind of cloth, and then it is instantly to be fixed on the cloth, by passing it over a pan of coals of a gentle heat, or by going over it with a hot iron. In this latter case it is necessary to put a sheet of paper between the design and the iron. Then the design will remain on the cloth neatly and correctly.

To make a white powder,—Take a known quantity of gum mastic, and melt it in a glazed earthen pot over a slow fire; add to this $\frac{1}{30}$th part of virgin wax, and when the whole is melted, add as much fine white silver as the gum and wax will imbibe, taking great care all the while to stir it in proportion as the white is added. The whole, when well mixed, must undergo the same preparation as the black powder.

DIRECTIONS FOR ACQUIRING A KNOWLEDGE OF THE FIXED STARS.

BY DAVID THOMSON.

In a recent number of this work we gave a short account of an extensive and neatly executed Celestial Atlas. Since the publication of that number we have seen a small work, containing directions for acquiring a knowledge of the principal fixed stars, without maps or diagrams. The method of accomplishing this is by *imaginary lines*, which are supposed to be drawn from some conspicuous star, or cluster of stars, previously known, through others that are also known, in order to point out some star which is unknown; and afterwards to serve as an index to it, when it is required to be distinguished from others.

This plan is not *new*, but it is here adopted more extensively than in any other work we have met with; and we are convinced, that if the imaginary lines and figures to which the stars are referred in this little work be traced by the eye of a discerning spectator, they will point out, and also serve to fix on the mind the relative places of the principal fixed stars. This to some may appear a matter of little moment; but to the *mariner* who traverses the pathless ocean, and has not only the *property*, but the *lives* of his fellow-creatures under his care, it is of the very *utmost* importance. And, as the intelligent author of this little work very justly observes, "It is much to be lamented that many who have the charge of vessels at sea, should have so little knowledge of the stars, which often afford opportunities of ascertaining the situation of a ship during the night, when observations of the sun cannot be obtained perhaps for several days together. The navigator, therefore, who is accustomed to determine the place of his ship by means of the stars, has a very great advantage, both as regards safety and dispatch, over the one who trusts entirely to observations of the *sun*."

The justness of these observations cannot be denied; and yet, strange to say, a very great proportion of mates and captains of merchant vessels are so little acquainted with the stars, as to be incapable of distinguishing one from another, at least for any useful purpose. But the intelligent seaman knows that the true situation of any place upon the earth can only be determined by means of a body in the heavens, and that every star he can *see* has its *latitude*, *longitude*, &c. better settled than any spot upon the earth; and consequently may be employed for this latter purpose, even in the midst of the trackless ocean, when the sun and moon are not to be seen.

The little work before us cannot fail to be useful to those who go to *sea*, as it contains a number of examples of finding the latitude, &c. both by the Sun and Stars; and likewise several valuable tables, one of which appears to us to be *new*, and must be useful both at sea and land, to all those who are accustomed to make observations on the stars.

This is a table containing the time to be added to the right ascension of a star, to find the time of its passing the meridian on any day of the year. This table we may, perhaps, take the liberty of inserting in another part of this work.

We perceive that the small work which we have here thought proper to notice, is to form an appendix or supplement to a larger work, containing a set of Lunar and Horary Tables, intended for finding the *Longitude* at Sea by means of Lunar Observations and Chronometers. This work we may also be induced to notice when it makes its appearance, as we conceive that whatever tends to improve the art of navigation, must also improve the trade and resources of this commercial country.

SOLUTIONS OF QUESTIONS.

Quest. 40, *answered by* G. G. C. *(the proposer.)*

As the weights of balls are as the cubes of their diameters; and as an iron ball 4 inches diameter, weighs 9 lbs; the diameter of the ball or orifice in question, will be $(32 \times 7\frac{1}{9})^{\frac{1}{3}} = 6{\cdot}105142$ inches, and its area $(6{\cdot}105142)^3 \times {\cdot}7854 \div 144$, or ·2032914 sq. foot. Now the velocity with which the water is $= 2\,(16\frac{1}{12} \times 8)^{\frac{1}{2}} = 22{\cdot}686266$ feet per second, and the quantity of water that enters in 1 second, is $22{\cdot}68626 \times {\cdot}2032914$, or 4·611922 cubic feet; consequently, in 10 minutes there will enter $4{\cdot}611922 \times 600 = 2767{\cdot}1532$ cubic feet of sea water, which at 1030 oz. per cubic foot, weighs, 79 tons 10 cwt 1 qr. 27 lb 7oz.

As the actual discharge is to the theoretical discharge as 62 to 1 (see Artisan, page 59), the above quantity diminished in this ratio, is 49 tons, 6 cwt. 12 lb.

Another gentleman sent us a solution of this question; but he will perceive, by the above, that the latter part of his solution is erroneous. Ed.

Quest. 41, (page 272) *answered by* J. Johnston, *Elm-street, Gray's-inn-lane.*

Multiply the number of beats in a minute by itself, and divide the number 141120* by the product, which will give the length in inches.

To apply this in the present question, let equal the number of beats, and it must also equal the number of inches. Then, $\frac{141120}{a^2} = a$, or $141120 = a^3$, the cube of the unknown number: the cube root of which is 52·7, the number of inches in length, and beats in a minute, or 3124 in an hour.

This question was also correctly solved by Mr. J. Whitcombe, *Cornhill*, and by the *Proposer*.

By mistake there is a question at page 228, which is also numbered 41; but though we have received four different solutions to it, we cannot insert *any* of them, till we have leisure to examine them, for no *two* of them *nearly* agree. Ed.

QUESTIONS FOR SOLUTION.

Quest. 45, *proposed by* Mr. J. Taylor.

Observing 2 men forcing round a screw, whose threads were one inch asunder; and the lever applied to the head of the screw, was 10 feet long: from this data I demand the *pressure* of the screw, the workmen urging the lever with a force equal to 200 pounds?

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* This number is found by squaring 60, the beats in a minute, and multiplying the product by 39·2 inches, the length of a pendulum that vibrates seconds.

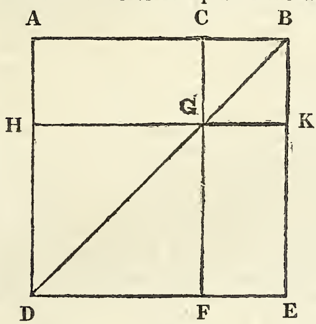
GEOMETRY.

PROPOSITION VII.

Theorem.—*If a straight line be divided into any two parts, the squares of the whole line, and of one of the parts, are equal to twice the rectangle contained by the whole and that part, together with the square of the other part.*

Let the straight line A B be divided into any two parts in the point C; the squares of A B, B C, are equal to twice the rectangle A B, B C, together with the square of A C.

Upon AB describe the square of ADEB, and construct the figure as in the preceding propositions; and because A G is equal to G E, add to each of them C K; the whole A K is therefore equal to the whole



C E; therefore A K, C E, are double of A K: But A K, C E, are the gnomon AKF, together with the square C K; therefore the gnomon AKF, together with the square C K, is double of A K: But twice the rectangle A B, B C, is double of A K, for B K is equal to B C: Therefore the gnomon A K F, together with the square C K, is equal to twice the rectangle A B, B C: To each of these equals add H F, which is equal to the square of A C; therefore the gnomon A K F, together with the squares C K, H F, is equal to twice the rectangle A B, B C, and the square of A C: But the gnomon A K F, together with the squares C K, H F, make up the whole figure A D E B and C K, which are the squares of A B and B C: therefore the squares of A B and B C are equal to twice the rectangle A B, B C, together with the square of A C. Wherefore, if a straight line, &c. Q. E. D.

Cor. The square on the difference of two lines, is equal to the square of those lines diminished by twice their rectangle.

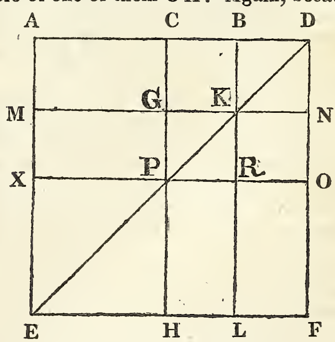
Let the whole line be 12, and let it be divided into the two parts 8 and 4: Then the square of (12) the whole line is 144, and the square of (4) one of the parts, is 16; the sum of these is 160. Now the rectangle of 12 and 4 is 48, and twice their rectangles is 96, to which add the square of the other part (8), or 64, and the sum will also be 160. Hence the truth of the proposition is established.

PROPOSITION VIII.

Theorem.—*If a straight line be divided into any two parts, four times the rectangle contained by the whole line, and one of the parts, together with the square of the other part, is equal to the square of the straight line, which is made up of the whole and that part.*

Let the straight line A B be divided into any two parts in the point C; four times the rectangle A B, B C, together with the square of A C, is equal to the square of the straight line made up of A B and B C together.

Produce A B to D, so that B D be equal to C B, and upon A D describe the square A E F D; and construct two figures such as in the preceding. Because C B is equal to B D, and that C B is equal to G K, and B D to K N; therefore G K is equal to K N: For the same reason, P R is equal to R O; and because C B is equal to B D, and G K to K N, the rectangle C K is equal to B N, and G R to R N; but C K is equal to R N, because they are the complements of the parallelogram C O; therefore also B N is equal to G R; and the four rectangles B N, C K, G R, R N are therefore equal to one another, and so are quadruple of one of them C K: Again, because



C B is equal to B D, and that B D is equal to B K, that is, to C G; and C B equal to G K, that is, to G P; therefore C G is equal to G P: and because C G is equal to G P, and P R to R O, the rectangle A G is equal to M P, and P L to R F: But M P is equal to P L, because they are the complements of the parallelogram M L; wherefore A G is equal also to R F: Therefore the four rectangles A G, M P, P L, R F, are equal to one another, and so are quadruple of one of them A G. And it was demonstrated, that the four C K, B N, G R, and R N are quadruple of C K. Therefore the eight rectangles which contain the gnomon A O H, are quadruple of A K: and because A K is the rectangle contained by A B, B C, for B K is equal to B C, four times the rectangle A B, B C is quadruple of A K: But the gnomon A O H was demonstrated to be quadruple of A K; therefore four times the rectangle A B, B C, is equal to the gnomon A O H. To each of these add X H, which is equal to the square of A C: Therefore four times the rectangle A B, B C together with the square of A C, is equal to the gnomon A O H and the square X H: But the gnomon A O H and X H make up the figure A E F D, which is the square of A D: Therefore four times the rectangle A B, B C, together with the square of A C, is equal to the square of A D; that is, of A B and B C added together in one straight line. Wherefore, if a straight line, &c. Q. E. D.

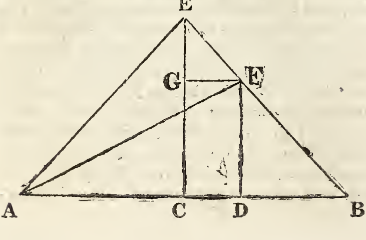
Let the whole line be 12, and the parts 8 and 4, as in the last proposition. Four times the rectangle of 12 and 4 is 192; to which add the square of (8) the other part, and the sum will be 256. Now the line made up of the whole (12) and the part (4) employed to form the rectangle, is 16, the square of which is 256, the same as the sum of the rectangles and square, which was to be shown.

PROPOSITION IX.

Theorem.—*If a straight line be divided into two equal, and also into two unequal parts; the squares of the two unequal parts are together double of the square of half the line, and of the square of the line between the points of section.*

Let the straight line A B be divided at the point C into two equal, and at D into two unequal parts: The squares of A D, D B are together double of the squares of A C, C D.

From the point C draw C E at right angles to A B, and make it equal to A C or C B, and join E A, E B; through D draw D F parallel to C E, and through F draw F G parallel to A B; and join A F: Then, because A C is equal to C E, the angle E A C is equal to the angle A E C; and because the angle A C E is a right angle, the two others A E C, E A C together make one right angle; and they are equal to one another; each of them,



therefore, is half of a right angle. For the same reason each of the angles C E B, E B C is half a right angle; and therefore the whole A E B is a right angle: And because the angle G E F is half a right angle, and E G F a right angle, for it is equal to the interior and opposite angle E C B, the remaining angle E F G is half a right angle; therefore the angle G E F is equal to the angle E F G, and the side E G equal to the side G F: Again, because the angle at B is half a right angle, and F D B a right angle, for it is equal to the interior and opposite angle E C B, the remaining angle B F D is half a right angle; therefore the angle at B is equal to the angle B F D, and the side D F to the side D B: And because A C is equal to C E, the square of A C is equal to the square of C E; therefore the squares of A C, C E, are double of the square of A C: But the square of E A is equal to the squares of A C, C E, because A C E is a right angle; therefore the square of E A is double of the square of A C: Again, because E G is equal to G F, the square of E G is equal to the square of G F; therefore the squares of E G, G F are double of the square of G F; but the square of E F is equal to the squares of E G, G F; therefore the square of E F is double of the square G F; and G F is equal to C D; therefore the square of E F is double of the square of C D: But the square of A E is likewise double of the square of A C; therefore the squares of A E, E F are double of the squares of A C, C D: And the square of A F is equal to the squares of A E, E F, because A E F is a right angle; therefore the square of A F is double of the squares of A C, C D: But the squares of A D, D F are equal to the square of A F, because the angle A D F is a right angle; therefore the squares of A D, D F are double of the squares of A C, C D: And D F is equal to D B; therefore the squares of A D, D B are double of the squares of A C, C D. If therefore a straight line, &c. Q. E. D.

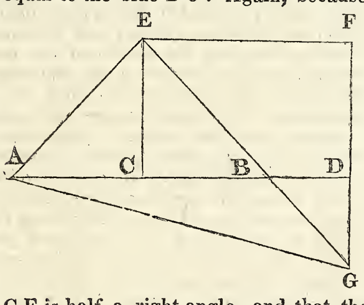
Let the whole line be 12, then each of the equal parts will be 6; and let the unequal parts be 8 and 4, consequently the part between the points of section, will be 2. Now the sum of the squares of the unequal parts is 80; and double the square of (6) half the line, is 72, to which add double the square of (2) the part between the points of section, and the sum will also be 80. Hence the truth of the proposition is established.

PROPOSITION X.

Theorem.—*If a straight line be bisected, and produced to any point, the square of the whole line thus produced, and the square of the part of it produced, are together double of the square of half the line bisected, and of the square of the line made up of the half and the part produced.*

Let the straight line A B be bisected in C, and produced to the point D; the squares of A D, D B are double of the squares of A C, C D.

From the point C draw C E at right angles to A B: And make it equal to A C or C B, and join A E, E B; through E draw E F parallel to A B, and through D draw D F parallel to C E: And because the straight line E F meets the parallels E C, F D, the angles C E F, E F D are equal to two right angles; and therefore the angles B E F, E F D are less than two right angles; but straight lines which with another straight line make the interior angles upon the same side less than two right angles, do meet if produced far enough: Therefore E B, F D shall meet, if produced towards B D: Let them meet in G, and join A G: Then, because A C is equal to C E, the angle C E A is equal to the angle E A C; and the angle A C E is a right angle; therefore each of the angles C E A, E A C is half a right angle: For the same reason each of the angles C E B, E B C is half a right angle; therefore A E B is a right angle; And because E B C is half a right angle, DBG is also half a right angle, for they are vertically opposite; but B D G is a right angle, because it is equal to the alternate angle D C E; therefore the remaining angle D G B is half a right angle, and is therefore equal to the angle D B G; wherefore also the side B D is equal to the side D G: Again, because



E G F is half a right angle, and that the angle at F is a right angle, because it is equal to the opposite angle E C D, the remaining angle F E G is half a right angle, and equal to the angle E G F; wherefore also the side G F is equal to the side F E. And because E C is equal to C A, the square of E C is equal to the square of C A; therefore the squares of E C, C A are double of the square of C A: But the square of E A is equal to the squares of E C, C A; therefore the square of E A is double of the square of A C: Again, because G F is equal to F E, the square of G F is equal to the square of F E; and therefore the squares of G F, F E are double of the square of E F: But the square of E G is equal to the squares of G F, F E; therefore the square of E G is double of the square of E F: And E F is equal to C D; wherefore the square of E G is double of the square of C D: But it was demonstrated, that the square of E A is double of the square of A C; therefore the squares of A E, E G are double of the squares of A C, C D: And the square of A G is equal to the squares of AE, E G; therefore the square of A G is double of the squares of A C, C D: But the squares of A D, G D are equal to the square of A G; therefore the squares of A D, D G are double of the squares of A C, C D: But D G is equal to D B; therefore the squares of A D, D B are double of the squares of A C, C D. Wherefore, if a straight line, &c. Q. E. D.

This proposition is exactly like the preceding, if the sum of the half line and produced part be considered the part between the points of section.

Thus let the line be 12 as before, and the part produced, or added 2; then the whole line thus produced or formed, will be 14, and the half line and produced part will be 8. Now the square of the whole line (14) is 196, and the square of (2) the part produced, or added is 4, therefore their sum is 200; but double the square of half the line (6) is 72, and double the square of the half line and produced part (8) is 128, the sum of which is 200, therefore the truth of the proposition is established.

MECHANICS.

ON THE REGULATION OF MACHINERY.

Amid the great variety of machines which have been applied to the practical purposes of life, there is scarcely one in which there is not a deviation from a uniformity of action, arising either from the nature of the impelling power, from the nature of the machinery to which it is applied, or from the nature of the work to be performed.

1. When horses or men are the first movers of machinery, the mechanical force which they exert is liable to great variation. When fresh and vigorous, they act with considerable force and steadiness; but after pulling for some time, the commencement of fatigue impairs their activity; and when they have to strive against a great resistance, they indulge in frequent and short relaxations, and then recommence their labour with renewed vigour. A constant variation in the velocity of the machine, is the necessary consequence of this unequal action, and by this means the communicating parts of the machinery are not only injured, but the work itself is often ill performed, and the animal is subject to additional fatigue, in dragging the whole machinery from a state of rest.

When the first mover is inanimate, an inequality of force evidently arises from a variation in the velocity of the wind, from an increase or diminution of water, arising from sudden rains and great droughts; or from an increase or decrease of steam in the boiler, arising from a variation in the heat of the furnace. In the spiral spring, too, its force is a maximum when it begins to uncoil itself, and it gradually diminishes till its force is entirely exhausted.

A desultory motion in machines arises also from the nature of the machinery by which the power is applied. In the single-stroke steam engine, the impelling power is so unequal, that for two or three seconds it does not act at all; and even in the double-stroke steam engine, the beam and all its appendages are brought completely to rest, and must be again dragged into motion at the returning stroke. In applying his power by means of a crank, a man exerts the greatest force when he pulls the handle upwards from the height of his knee; and his force is a minimum, when the handle being in a vertical position, is thrust from him in a horizontal direction. Hence Desaguliers found, that when this irregularity was corrected by placing two handles at right angles to one another, and making two men drive them, their individual action was 35, whereas with one handle it was only 30.

A variation of velocity may frequently arise from the nature of the work to be performed. In thrashing-mills on a small scale, when too much of the corn is taken in by the fluted rollers, the increase of resistance immediately retards the machinery, and communicates a desultory motion even to the water-wheel itself. In the pile engine invented by M. Vauloue, a similar variation arises from the nature of the work, which is to raise a great weight in order to drive piles. The machine is drawn by horses, and as soon as the ram or weight is elevated and discharged, the resistance against which the horses have been struggling is suddenly removed, and they would instantly fall to the ground, were not this sudden diminution in the resistance counteracted by a mechanical contrivance.

The simplest of all contrivances for regulating machinery, are *fly-wheels*, which are nothing more than large heavy wheels driven with great velocity, by the machinery to which they are attached.

The use of the fly-wheel is to facilitate the motion of engines, by accumulating and retaining the power communicated to it gradually and equally in each revolution of the machine; whence it comes to pass that the motion of the machine is rendered very nearly uniform and equal in all parts of the revolution, and therefore more easy, pleasant, and convenient.*

The best form for a fly is that of a heavy wheel or circle, of a fit size; for this will meet with less resistance from the air; and being continuous, and the weight every where equally distributed through the perimeter of the wheel, the motion will be more easy, equable, and regular. In this form the fly is most aptly applied to the perpendicular drill, where it not only gives weight and regularity of motion, but contributes to keep the drill upright by its centrifugal power.

In this form it is also best applied to a windlass or common winch, where the motion is pretty quick; for when a man turns the bended handle of the winch, his strength is not, nor can be equally exerted in every part of the revolution; for in pulling upwards from the lower quarter, he can exercise more power than in thrusting forward in the upper quarter, where, of course, part of his former force would be lost, were it not accumulated and conserved in the equable motion of the fly. By this means a man may work all day in drawing up a weight of 40 lb.; whereas 30 lb. would create him more labour in a day without the fly.

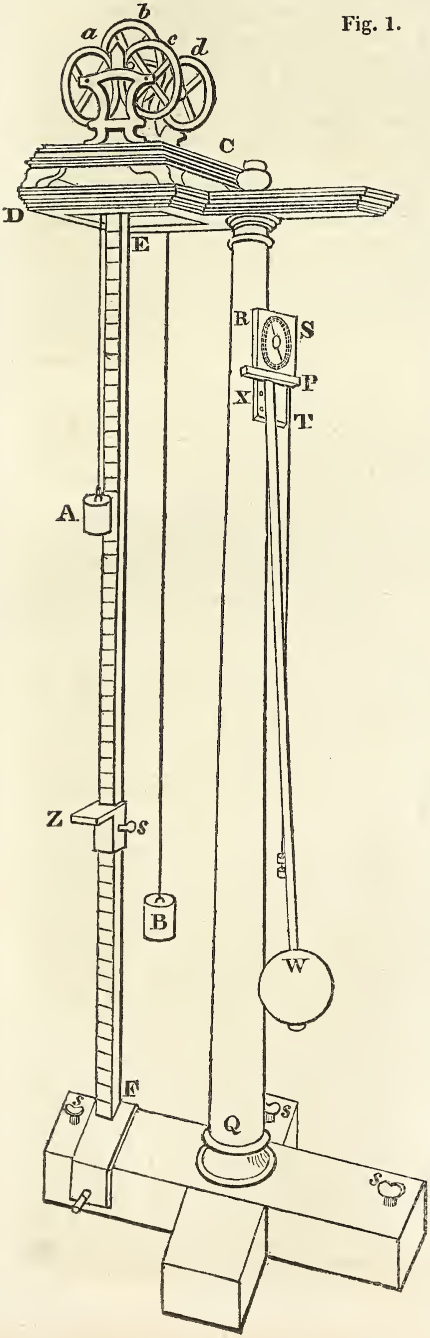
When a fly-wheel is put in motion, it derives a very high momentum from its great weight and velocity, and may therefore be regarded as a sort of reservoir of power, by which the machine is supplied with velocity whenever there is any defalcation in the moving power, any intervals of rest arising from the nature of the machinery, or any inequality of resistance arising from the nature of the work to be performed. In the single steam-engine, for example, while the piston is descending, and when no impelling power is exerted, the momentum of the fly keeps up the rotatory motion of the machinery, till the impelling force is again exerted during the ascent of the piston. In Vauloue's pile engine, when the resistance is suddenly removed, the horses are prevented from falling solely by the momentum of a heavy fly-wheel, against which their force is exerted, till the ram or weight is again raised. Fly-wheels are sometimes made with vanes, which regulate the descent of a weight by the increased resistance of the air; but they are not much used in machinery.

* The fly does not give any new power to an engine as some have imagined: as is evident for the following reasons:—1. The fly has no motion but what it receives at first from the machine. 2. A degree of force is always necessary to maintain the motion of the fly, which must be supplied from the machine. 3. The friction of the pivot, screw, &c. of the fly, is a resistance to the impressed force, and must abate it. 4. The air likewise makes resistance to the weights at the end of the fly. Upon all which accounts it is easy to understand, that the fly, instead of adding, does very much decrease or lessen the power impressed on the machine.

OF ATWOOD'S MACHINE.

This ingeuious machine, which is represented by the following figure,

Fig. 1.



was invented by Mr. Atwood, for the purpose of illustrating the doctrines of accelerated and retarded motion; and by means of it we are enabled to ascertain experimentally, 1. The quantity of matter moved; 2. The moving force; 3. The space described; 4. The time in which the space is described; and 5. The velocity acquired at the end of that time.

This machine consists of a fixed brass pulley or wheel *a b c d*, moving upon a horizontal axis of steel. Each extremity of this axis rests upon two friction wheels, whose axis are horizontal, and the whole is placed upon a platform C D, placed at the top of a vertical pillar C Q, whose base can be put into a true horizontal position by the screws *s*, *s*, *s*. The height of the machine is about eight feet, the greatest diameter of the wheel *a b c d*, is about seven inches and five-tenths, the depth of the groove upon its circumference about one-fourth of an inch, and the diameter of the friction rollers about five inches.

A pendulum P W is carried by the shelf R S T, as in the following figure.

Fig. 2.

The plane of the dial plate is parallel to that of the wheel *a b c d*. Between the platform C D, and the base *s s* of the pillar C Q, there rises an upright E F, whose section is a rectangular parallelogram, the length of the sides being about one inch and six-tenths, and two inches and one-tenth. The narrowest face is parallel to that of the wheel *a b c d*, and carries a divided scale about 64 inches long, and subdivided into inches and tenths.

In the following account of the method of using this machine, we have implicitly followed the description given by Mr. Atwood himself.

Of the quantity of matter moved.—In order to observe the effects of the moving force, which is the object of any experiment, the interference of all other forces should be prevented; the quantity of matter moved, therefore, considering it before any impelling force has been applied, should be without weight; for though it be impossible to abstract weight from any substance whatever, yet it may be so counteracted as to produce no sensible effect Thus in the machine, Fig. 1. A and B represent two equal weights affixed to the extremities of a very fine silk thread, stretched over a wheel or fixed pulley *a b c d*, moveable round a horizontal axis: the two weights A, B, being equal, and acting against each other, remain in equilibrio; and when the least weight is superadded to either (setting aside the effects of friction), it will preponderate. When A, B are set in motion by the action of any weight *m*, the sum $A + B + m$, would constitute the whole mass moved, but for the inertia of the materials which must necessarily be used in the communication of motion. These materials consist of, 1. The wheel *a b c d*, over which the thread sustaining A and B passes. 2. The four friction wheels on which the axle of the wheel *a b c d* rests. 3. The thread by which the bodies A and B are connected, so as when set in motion to move with equal velocities. The weight and inertia of the thread are too small to have any sensible effect on the experiments; but the inertia of the other materials constitute a considerable proportion of the mass moved, and must therefore be taken into account. Since when A and B are put in motion, they must move with a velocity equal to that of the circumference of the wheel *a b c d*, to which the thread is applied; it follows, that if the whole mass of the wheels were accumulated in this circumference, its inertia would be truly estimated by the quantity of matter moved; but since the parts of the wheels move with different velocities, their effects in resisting the communication of motion to A and B by their inertia, will be different; those parts which are furthest from the axis, resisting more than those which revolve nearer in a duplicate proportion of those distances. If the figures of the wheels were regular, the distances of their centres of gyration from their axis of motion would be given, and consequently an equivalent weight, which being accumulated uniformly in the circumference *a b c d*, would exert an inertia equal to that of the wheels in their constructed form, would also be given. But as the figures are irregular, recourse must be had to experiment, to assign that quantity of matter, which being accumulated uniformly in the circumference of the wheel *a b c d*, would resist the communication of motion to A in the same manner as the wheels.

In order to ascertain the inertia of the wheel *a b c d* with that of the friction wheels, the weights A, B being removed, the following experiment was made:

A weight of 30 grains was affixed to a silk thread of inconsiderable weight; this thread being wound round the wheel *a b c d*, the weight 30 grains by descending from rest communicated motion to the wheel, and by many trials was observed to describe a space of about $38\frac{1}{2}$ inches in 3 seconds. From these data the equivalent mass or inertia of the wheels will be known from this rule.

Let a weight P, suppose 30 grains, fig. 2, be applied to communicate motion to a system of bodies, by means of a very slender and flexible thread going round the wheel S L D I M, through the centre of which the axis passes, (G being the *common* centre of gravity, R the centre of gravity of the matter contained in this line, and O the centre of oscillation). Let this weight descend from rest through any convenient space, suppose $38\frac{1}{2}$ inches, and suppose that the observed time of its descent is 3 seconds; then, as the space through which bodies descend by the force of gravity, in one second of time, is $16\frac{1}{12}$ feet, or 193 inches; the equivalent weight sought will be $\frac{193 \times 3^2 \text{ (or 9)} \times 30}{38\cdot 5} - 30 = 1323$ grains, or 2 and $\frac{3}{4}$ ounces.

This is the *inertia* or resistance equivalent to that of the wheel *a b c d*, and the friction wheels together; for the rule extends to the estimation of the *intertia* of the *mass* contained in *all* the wheels.

The resistance to motion, therefore, arising to the wheels' inertia, will be the same as if they were absolutely removed, and a mass of $2\frac{3}{4}$ ounces uniformly accumulated in the circumference of the wheel *a b c d*. This being premised, let the boxes A and B be re-placed, and suspended by the silk thread over the wheel or pulley *a b c d*,, and exactly balancing each other: then let any weight (*m*), suppose 4 ounces, be added to A, so that it shall descend, the exact quantity of matter moved during the descent of the weight A, will be ascertained; for the whole will be $A + B + 4 + 2\frac{3}{4}$ ounces.

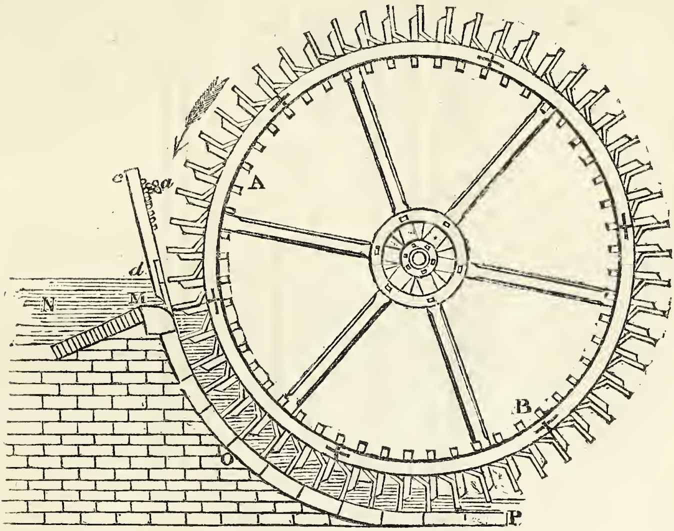
In order to avoid troublesome computations, in adjusting the quantities of matter moved and the moving forces, some determinate weight of convenient magnitude may be assumed as a standard, to which all the others are referred. This standard weight in the subsequent experiments is $\frac{1}{4}$ of an ounce, and is represented by the letter *m*. The inertia of the wheels being therefore $= 2\frac{3}{4}$ or $\frac{11}{4}$ ounces, will be denoted by 11 *m*. A and B are two boxes, constructed so as to contain different quantities of matter, according as the experiment may require them to be varied; the weight of each box, including the hook to which it is supended $= 1\frac{1}{2}$ oz. or according to the preceding estimation, the weight of each box will be denoted by 6 *m*; these boxes contain weights, each of which weights is an ounce, equivalent to 4 *m*; other weights of $\frac{1}{2}$ oz. $= 2\,m$, $\frac{1}{4} = m$, and aliquot parts of *m*, such as $\frac{1}{2}\,m$, $\frac{1}{4}\,m$, may be also included in the boxes.

HYDRAULICS.

ON BREAST WHEELS.

A breast water wheel is a wheel in which the water is delivered at a point intermediate between the upper and under point of a wheel with float-boards. It is generally delivered at a point below the level of the axis, but sometimes at a point a little higher than the level of the axis. On breast wheels buckets are never employed, but the float-boards are fitted accurately, with as little play as possible, to the mill course, so that the water, after acting upon the float-boards by its impulse, is retained between the float-boards and the mill course, and acts by its weight till it reaches the lowest part of the wheel.

A breast wheel, as constructed by Mr. Smeaton, is represented by the following figure,



where A B is a portion of the wheel, M N the canal which conveys the water to the wheel, M O P the curvilineal mill course accurately fitted to the extremities of the float-boards, and *c d* the shuttle moved by a pinion *a*, for the purpose of regulating the admission of water upon the wheel.

M. Lambert observes, that when the fall of water is between 4 and 10 feet, a breast water wheel should be erected, provided there is enough of water; that an undershot wheel should be used when the fall is below 4 feet, and an overshot wheel when the fall exceeds 10 feet. He recommends also that when the fall exceeds 10 feet, it should be divided into two, and two breast wheels erected upon it. These rules are, however, not of great value.

COMPARATIVE EFFECTS OF WATER WHEELS.

M. Belidor very strangely maintained, that overshot wheels were inferior to undershot ones. It appears, however, from Smeaton's experiments, that in overshot wheels the ratio of the power to the effect is nearly as 3 to 2, or as 5 to 4, whereas, in undershot wheels the ratio is only as 3 to 1; from which it follows, that the effect of overshot wheels is nearly double of the effect of undershot wheels. The Chevalier de Borda has concluded, that overshot wheels will raise through the height of the fall, a quantity of water equal to that by which they are driven; that undershot wheels moving vertically, will produce $\frac{3}{8}$ths of this effect; that horizontal wheels will produce a little less than $\frac{1}{2}$ of it when the float-boards are plain, and a little more than $\frac{1}{2}$ when they are curvilineal.

MACHINES MOVED BY THE RE-ACTION OF WATER.

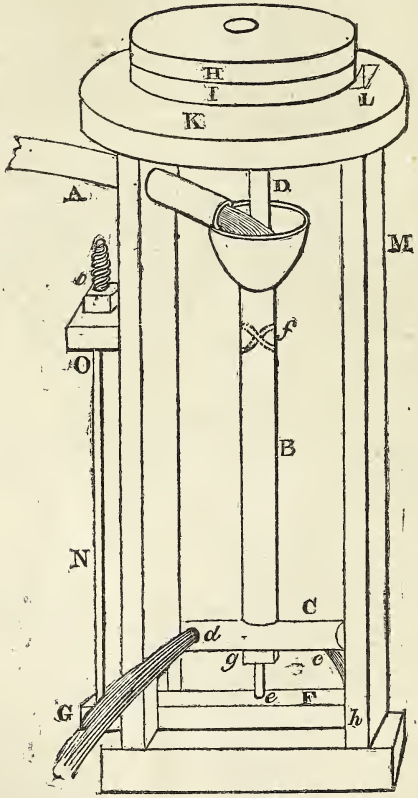
Some machines are moved, not directly by the impulse of a stream of water, but indirectly by the relief from pressure which the motion of the stream occasions.

The machine known by the name of BARKER's mill, is of this kind.

BARKER'S MILL.

The first mills which were driven by the re-action of water were called *Barker's* mill, and sometimes *Parent's* mill.

This machine is represented by the following figure,



in which, A is a pipe or channel that brings water to the upright tube B. The water runs down the tube, and thence into the horizontal trunk C, and runs out through holes at *d* and *e*, near the ends of the trunk on the contrary sides thereof.

The upright spindle D is fixed in the bottom of the trunk, and screwed to it below by the nut *g*; and is fixed into the trunk by two cross bars at *f*: so that, if the tube B and trunk C be turned round, the spindle D will be turned also.

The top of the spindle goes square into the rynd of the upper mill-stone H, as in common mills; and, as the trunk, tube, and spindle turn round, the mill-stone is turned round thereby. The lower, or quiescent mill-stone is represented by I; and K is the floor on which it rests, and wherein is the hole L for letting the meal run through, and fall down into a trough which may be about M. The hoop or case that goes round the mill-stone rests on the floor K, and supports the hopper, in the common way. The lower end of the spindle turns in a hole in the bridge-tree G F, which supports the mill-stone, tube, spindle, and trunk. This tree is moveable on a pin at *h*, and its other end is supported by an iron rod N fixed into it, the top of the rod going through the fixed bracket O, and having a screw-nut *o* upon it, above the bracket. By turning this nut forward or backward, the mill-stone is raised or lowered at pleasure.

Whilst the tube B is kept full of water from the pipe A, and the water continues to run out from the ends of the trunk; the upper mill-stone H, together with the trunk, tube, and spindle, turns round. But, if the holes in the trunk were stopt, no motion would ensue; even though the tube and trunk were full of water. For, if there were no hole in the trunk, the pressure of the water would be equal against all parts of its sides within. But, when the water has free egress through the holes, its pressure there is entirely removed: and the pressure against the parts of the sides which are opposite to the holes, turns the machine.

In the preceding form of Barker's mill, the length of the axis must always exceed the height of the fall, and therefore when the fall is very high, the difficulty of erecting such a machine would be great. In order to remove this difficulty, M. Mathon de la Cour proposes to introduce the water from the mill course into the horizontal arms, which are fixed to the upright spindle, but without any tube. The water will obviously issue from the apertures, in the same manner as if it had been introduced at the top as high as the fall. Hence the spindle D may be made as short as we please. The practical difficulty which attends this form of a machine, is to give the arms a motion round the mouth of the feeding pipe, which enters the arm without any great friction, or any considerable loss of water.

In the year 1747, Professor Segner, of Gottingen, published, in his *Exercitationes Hydraulicæ*, an account of a machine which differs only in form from Dr. Barker's mill. It consisted of a number of tubes arranged as it were in the circumference of a truncated cone; the water was introduced into the upper ends of these tubes, and flowing out at the lower ends, produced, by virtue of its re-action, a motion round the axis of the cone.

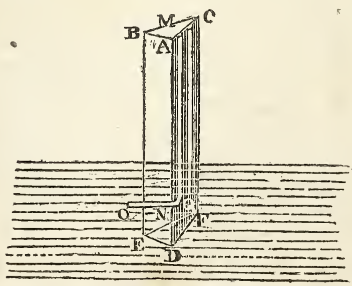
Another form of this machine has been suggested by Albert Euler. He proposes to introduce the water from the mill course into an annular cavity in a fixed vessel, of the shape nearly of a cylinder. The bottom of this vessel has several inclined apertures, for the purpose of making the water flow out with a proper obliquity into the inferior and moveable vessel. This inferior vessel, which has the form of an inverted frustum of a cone, moves about an axis passing up through the centre of the fixed vessel, and has a variety of tubes arranged round its circumference. These tubes do not reach to the very top of the vessel, and are bent into right angles at their lower ends. The water from the upper and fixed vessel being delivered into the tubes of the lower vessel, descends in the tubes, and issuing from their horizontal extremities, gives motion to the conical drum by its re-action.

The excellence of this method of employing the re-action of water, was first slightly pointed out by Dr. Desaguliers, and no further notice seems to have been taken of the invention, till the appearance of Segner's machine in 1747. The attention of Leonhard Euler, John Bernoulli, and Albert Euler, was then directed to the subject, and it would appear, from the results of their investigations, that this is the most powerful of all hydraulic machines, and is therefore the best mode of employing water as a moving power. Leonhard Euler published his theory of this machine in the Memoirs of the *Berlin* Academy, and the application of the machine to all kinds of work, was explained in a subsequent paper in the same work, for 1752, p. 271. John Bernoulli's investigations will be found at the end of his *Hydraulics*.

Albert Euler concluded, that when the machine had the form given to it by Segner, the effect was equal to the power, and that the effect is a maximum when the velocity is infinite. Mr. Waring makes the effect of the machine equal only to that of a good undershot wheel, driven with the same quantity of water falling through the same height. The Abbé Bossut has likewise investigated the theory of this machine, and has found that an overshot wheel, and a wheel of the form given to it by Albert Euler, will produce equal effects with the same quantity of water, if the depth of the orifice below the mill-course in the latter machine, be equal to the vertical height of the loaded arch in the overshot wheel; and he, upon the whole, recommends the overshot wheel as preferable in practice. The preceding result, however, proves the inferiority of the overshot wheel, as the height of the loaded arch must be always much less than that of the fall. A new and ingenious theory of this machine has lately been given by Mr. Ewart in the *Manchester Memoirs*.

PITOT'S BENT TUBE FOR MEASURING THE VELOCITY OF WATER.

One of the most ingenious instruments for measuring the velocity of water, is the *tube recourbé*, or bent tube invented by M. Pitot. It is represented by the following figure,



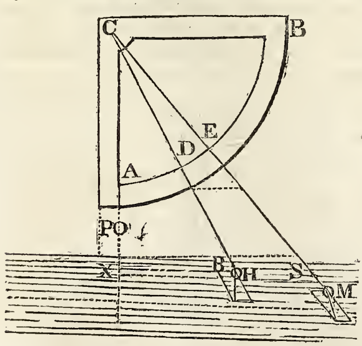
and consists of a prism of wood ABCDEF, one of the angles of which is presented to the current. On the hinder face BCFE are fixed two tubes of glass parallel to each other, and having a graduated scale between them: one of them; viz. MNO, being bent into a right angle at O, so that the part MN may pass through the prism horizontally. When this instrument is plunged into a running stream, the general level of the current is shown by the rise of the water in the straight tube PQ, while the height of the water in the bent tube MNO, becomes the measure of the force of the stream. The difference between these heights will therefore be the height due to the velocity. In the practical use of this instrument, it is, however, difficult to fix it sufficiently steady to prevent the water from oscillating in the tubes.

M. Du Buat having examined the instrument experimentally, found that it could be trusted no further, than to give the *ratio* of different velocities. He therefore suppressed the tube PQ altogether, and substituted in place of the bent tube of glass MNO, a simple tube of white iron, sufficiently large to admit a float for pointing out the height of the water in the tube. The lower end of this tube is bent back as at MN, and is terminated by a plane surface perforated at its centre with a small orifice, which will greatly diminish the oscillations of the elevated column.

If we then take *two-thirds* of the height of the water in the tube above the level of the stream, we shall have, very exactly, the height due to the velocity of the current, for the depth to which the orifice is immersed.

HYDRAULIC QUADRANT FOR MEASURING THE VELOCITY OF WATER.

The *hydraulic quadrant* which has been recommended by several authors for measuring the velocity of water, is represented by the following figure.



It consists of a quadrant ABC, with a divided arch AB, and having two threads moving round its centre. One of these CP is short, and carries a weight P, which always hangs in the air, while the other CH or CM is longer, and caries a weight, whose specific gravity is greater than that of water, and which plunges more or less deep in the current as the thread is lengthened. The instrument is then held as in the figure, so that the plummet CP passes through O; and the angle ACD, or the angular distance of the other thread from a vertical line, will be a measure of the force, and consequently of the velocity of the current.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF ROGER BACON, COMMONLY CALLED FRIAR BACON.

Roger Bacon, a learned English monk of the Franciscan order, who flourished in the thirteenth century, was born near Ilchester, in Somersetshire, in 1214, and was descended of a very ancient and honourable family. He received the first tincture of letters at Oxford, where having gone through Grammar and Logic, the dawnings of his genius gained him the favour and patronage of the greatest lovers of learning, and such as were equally distinguished by their high rank, and the excellence of their knowledge. "It is not very clear," says the Biographia Britannica, "whether he was of Merton College, or of Brazen-nose Hall, and perhaps he studied at neither, but spent his time at the public schools." It appears, however, that he went early over to Paris, where he made still greater progress in all parts of learning, and was looked upon as the glory of that University, and an honour to his country. In those days, persons who wished to distinguish themselves by an early and effectual application to their studies, resorted to Paris, where not only many of the greatest men in Europe resided and taught, but many of the English nation, by whom Bacon was encouraged and caressed. At Paris he did not confine his studies to any particular branch of literature, but endeavoured to comprehend the sciences in general, fully and perfectly, by a right method and constant application. When he had attained the degree of Doctor, he returned again to his own country, and, as some say, took the habit of the Franciscan order, in 1240, when he was about twenty-six years of age. After his return to Oxford, he was considered, by the greatest men of that University, as one of the ablest and most indefatigable enquirers after knowledge that the world had ever produced; and therefore they not only showed him all due respect, but likewise conceiving the greatest hopes from his improvements in the method of study, they generously contributed to his expenses, so that he was enabled to lay out, within the compass of twenty years, no less than two thousand pounds in collecting curious Authors, making experiments of various kinds, and in the construction of different instruments, for the improvement of useful knowledge. But if this assiduous application to his studies, and the stupendous progress he made in them, raised his credit with the better part of mankind, it excited the envy of some, and afforded plausible pretences for the malicious designs of others. It is very easy to conceive, that the experiments he made in all parts of Natural Philosophy and the Mathematics, must have made great noise in an ignorant age, when scarcely two or three men in a whole nation were tolerably acquainted with those studies, and when all the pretenders to knowledge affected to cover their own ignorance, by throwing the most scandalous aspersions on those branches of science, which they either wanted genius to understand, or which demanded greater application to acquire, than they were willing to bestow. They gave out, therefore, that Mathematical studies were in some measure allied to those magical arts which the *church* had condemned, and thereby brought suspicions upon men of superior learning. It was owing to this suspicion, that Bacon was restrained from reading lectures to the young students in the University, and at length closely confined and almost starved, the Monks being afraid, lest his writings should extend beyond the limits of his convent, and be seen by any besides themselves and the Pope. But there is great reason to believe, that though his application to the occult sciences was their pretence, the true cause of his ill-usage was, the freedom with which he had treated the clergy in his writings, in which he spared neither their ignorance nor their want of morals. But notwithstanding this harsh feature in the character of the times, his reputation continued to spread over the whole Christian world, and even Pope Clement IV. wrote him a letter, desiring that he would send him all his works. This was in 1266, when our author was in the flower of his age, and to gratify his Holiness, collected together, greatly enlarged and ranged in some order, the several pieces he had written before that time, and sent them the next year by his favourite disciple, John of London, or rather of Paris, to the Pope. This collection, which is the same that he entitled Opus Majus, or his great work, is yet extant, and was published by Dr. Jebb, in 1773. Dr. Jebb had proposed to have published all his works about three years before his edition of the Opus Majus, but while he was engaged in that design, he was informed by letters from his brother in Dublin, that there was a manuscript in the College library there, which contained a great many treatises generally ascribed to Bacon, and disposed in such order, that they seemed to form one complete work, but the title was wanting, which had been carelessly torn off from the rest of the manuscript. The Doctor soon found that it was a collection of those tracts which Bacon had written for the use of Pope Clement IV. and to which he had given the title of Opus Majus, since it appeared, that what he said of that work in his Opus Tertium, addressed to the same Pope, exactly suited with this; which contained an account of almost all the new discoveries and improvements that he had made in the sciences. Upon this account Dr. Jebb laid aside his former design, and resolved to publish only an edition of his Opus Majus. The manuscripts which he made use of to complete this edition, are, 1. MS. in the Cotton library, inscribed "Jul. D. V." which contains the first part of the Opus Majus, under the title of a treatise, "De utilitate Scientiarum." 2. Another MS. in the same library, marked "Tib. C. V." containing the fourth part of the Opus Majus, in which is shown the use of the mathematics in the sciences and affairs of the world; in the MS. it is erroneously called the fifth part. 3. A MS. in the library belonging to Corpus Christi, in Cambridge, containing that portion of the fourth part which treats of Geography. 4. A MS. of the fifth part, containing a treatise upon perspective, in the earl of Oxford's library. 5. A MS. in the library of Magdalen College, Cambridge, comprehending the same treatise of perspective. 6. Two MSS. in the king's library, communicated to the editor by Dr. Richard Bentley, one of which contains the fourth part of Opus Majus, and the other the fifth part. It is said that this learned book of his procured him the favour of Clement IV. and also some encouragement in the prosecution of his studies; but this could not have lasted long, as that Pope died soon after, and then we find our author under fresh embarrassments from the same causes as before; but he became in more danger, as the general of his order, Jerom de Ascoli, having heard his cause, ordered him to be imprisoned. This is said to have happened in 1278, and to prevent his appealing to Pope Nicholas III. the general procured a confirmation of his sentence from Rome immediately, but it is not very easy to say upon what pretences. Yet we are told by others, that he was imprisoned by Reymundus Galfredus, who was general of his order, on account of some alchemical treatise which he had written, and that Galfredus afterwards set him at liberty, and became his scholar. However obscure these circumstances may be, it is certain that his sufferings for many years must have brought him low, since he was sixty-four years of age when he was first put in prison, and deprived of the opportunity of prosecuting his studies, at least in the way of experiment. That he was still indulged in the use of his books, appears very clearly, from the great use he made of them in the learned works he composed.

After he had been *ten years* in *prison*, Jerom de Ascoli, who had condemned his doctrine, was chosen Pope, and assumed the name of Nicholas IV. As he was the first of the Franciscan order that had ever arrived at this dignity, he was reputed a person of great probity and much learning, our author, notwithstanding what had before happened, resolved to apply to him for his discharge; and in order to pacify his resentment, and at the same time to show both the innocence and the usefulness of his studies, he addressed to him a very learned and curious treatise, "On the means of avoiding the infirmities of old Age," printed first at Oxford, 1590, and translated and published by Dr. Richard Browne, under the title of "The cure of old Age and preservation of Youth," London, 1683, 8vo. It does not appear, however, that his application had any effect; on the contrary, some writers say that he caused him to be more closely confined. But towards the latter end of his reign, Bacon, by the interposition of some nobleman, obtained his release, and returned to Oxford, where he spent the remainder of his days in peace, and dying in the college of his order, on the 11th of June, 1292, was interred in the church of the Franciscans. The monks gave him the title of "Doctor Mirabilis," or the Wonderful Doctor, which he deserved, in whatever sense the phrase is taken.

He was certainly the most extraordinary man of his time. He was a perfect master of the Latin, Greek, and Hebrew, and has left posterity such indubitable marks of his critical skill in them, as might have secured him a very high character, if he had never distinguished himself in any other branch of literature. In all the branches of the mathematics he was well versed, and there is scarcely any part of them, on which he has not written with a solidity and clearness, which have been deservedly admired by the greatest masters in that science. In Mechanics particularly, the learned Dr. Freind says, "that a greater genius had not arisen since the days of Archimedes. He understood, likewise, the whole science of Optics, with accuracy; and is very justly allowed to have understood both the theory and practice of those discoveries, which have bestowed such high reputation on those of our own and of other nations, who have brought them into common use. In Geography also he was admirably well skilled, as appears from a variety of passages in his works, which was the reason that induced the judicious Hackluyt to transcribe a long discourse out of his writings, into his Collection of Voyages and Travels. But his skill in Astronomy was still more remarkable, since it appears, that he not only pointed out that error which occasioned the reformation in the Calendar, and the distinction between the old stile and the new, but also offered a much more effectual and perfect reformation, than that which was made in the time of Pope Gregory XIII. There are also remaining some works of his relating to Chronology, which would have been thought worthy of very particular notice, if his skill in other sciences had not made his proficiency in this branch of knowledge the less remarkable. The history of the four great empires of the world, he has treated very accurately and succinctly, in his great work addressed to Pope Clement IV. He was so thoroughly acquainted with Chemistry, at a time that it was scarcely known in Europe, and principally cultivated among the Arabians, that Dr. Freind ascribes the honour of introducing it to him, who speaks in some part or other of his works, of almost every operation now used in Chemistry. Three capital discoveries made by him deserve to be particularly considered. The first is, the invention of gun-powder, which however, confidently ascribed to others, was most unquestionably known to him, both as to its ingredients and effects. The second is that which commonly goes under the name of Alchemy, or the art of transmuting metals, of which he has left many treatises, some published, and some still remaining in MS., which, whatever they may be thought of now, contain a multitude of curious and useful passages, independently of their principal subject. The third discovery in Chemistry, not so deserving of the reader's attention, was the tincture of gold for the prolongation of life, of which Dr. Freind says, "he has given hints in his writings, and has said enough to show that he was no pretender to this art, but understood as much of it as any of his successors. That he was far from being unskilled in the art of Physic, we might rationally conclude, from his extensive knowledge in those sciences, which are connected with it: but we have a manifest proof of his perfect acquaintance with the most material and useful branches of physic, in his Treatise of Old Age, which, as Dr. Freind, whose authority on that subject cannot well be disputed, observes, is very far from being ill-written; and Dr. Brown, who published it in English, esteemed it one of the best performances that ever was written. In this work he has collected whatever he had met with upon the subject, either in Greek or Arabian writers, and has added a great many remarks of his own. In logic and metaphysics he was excellently well versed, as appears by those parts of his works, in which he has treated of these subjects: neither was he unskilled in Philology and the politer parts of learning. In Ethics, or Moral Philosophy, he has laid down some excellent principles for the conduct of human life.

As to the vulgar imputation on his character, of his leaning in magic, it was utterly unfounded; and the ridiculous story of his making a brazen head, which spoke and answered questions, is a calumny indirectly fathered upon him, having been originally imputed to Robert Grossetete, Bishop of Lincoln. That he had too high an opinion of judicial astrology, and some other arts of that nature, was not so properly an error of his as of the age in which he lived: and considering how few errors, among the many which infected that age, appear in his writings, it may be easily forgiven. As his whole life was spent in labour and study, and he was continually employed, either in writing for the information of the world, or in reading and making experiments, that might enable him to write with greater accuracy; so we need not wonder his works were extremely numerous, especially when it is considered, that on the one hand his studies took in the whole circle of the sciences, and that on the other, the numerous treatises ascribed to him, are often in fact, but so many chapters, sections, or divisions; and sometimes we have the same pieces under two or three different names: so that it is not at all strange before these points were well examined, that the accounts we have of his writings, appeared very perplexed and confused.

ARCHITECTURE.

CONSTRUCTION OF ARCHES.

If the weights of the voussoirs in an arch are all equal, the arch of equilibration is what is termed a *Catenarian* curve, the same that a chain or cord of uniform thickness would assume if hanging freely, the horizontal distance of the points of suspension, being equal to the span of the arch, and the depth of the lowest point of the chain being equal to the greatest height of the arch.

If the figure of the chain were reversed, the joints being such, that the force which was a *pull* in the first situation, becomes a *thrust* in the second, the chain would support itself, and remain in *equilibrio*.

The *catenaria* is remarkable for this mechanical property. That a chain hanging in that curve, has its centre of gravity *lower* than if it were disposed in any other line, its length continuing the same, and also the points from which it is suspended. Therefore an arch constructed in this form, has its centre of gravity the *highest* possible.

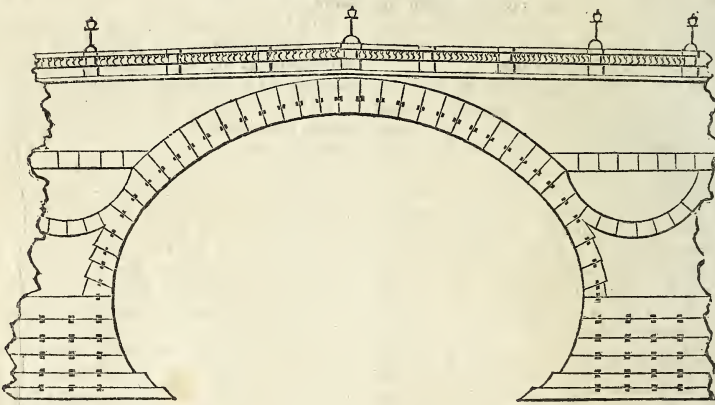
But the supposition of an arch resisting a weight, which acts only in a vertical direction, is by no means perfectly applicable to cases which generally occur in practice. The pressure of loose stones and earth, moistened as they frequently are by rain, is exerted very nearly in the same manner as the pressure of fluids, which act equally in all directions: and even if they were united into a mass, they would constitute a kind of wedge, and would thus produce a pressure of a similar nature, notwithstanding the precaution recommended by some authors, of making the surfaces of the arch-stones vertical and horizontal only. This precaution is, however, in all respects unnecessary, because the effect which it is intended to obviate, is productive of no inconvenience, except that of exercising the skill of the architect. The effect of such a pressure only requires a greater curvature near the abutments, reducing the form nearly to that of an ellipsis, and allowing the arch to rise at first in a vertical direction.

A bridge must also be so calculated, as to support itself without being in danger of falling by the defect of the lateral adhesion of its parts, and in order that it may in this respect be of equal strength throughout its depth at each point, must be proportional to the weight of the parts beyond it. This property particularly belongs to the curve denominated *logarithmic*, the length corresponding to the logarithm of the depth. If the strength were afforded by the arch stones only, this condition might be fulfilled by giving them the requisite thickness, independently of the general form of the arch: but the whole of the materials employed in the construction of the bridge, must be considered as adding to the strength, and the magnitude of the adhesion, as depending in a great measure on the general outline.

We must examine in the next place what is the most advantageous form for supporting any weight which may occasionally be placed on the bridge, particularly at its weakest part, which is usually the middle. Supposing the depth at the summit of the arch at the abutments to be given, it may be reduced considerably, in the intermediate parts, without impairing the strength, and the outline may be composed of *parabolic arcs*, having their convexity turned towards each other. This remark also would be only applicable to the arch stones, if they afforded the whole strength of the bridge, but it must be extended in some measure to the whole of the materials forming it.

If, therefore, we combine together the curve best calculated for resisting the pressure of a fluid, which is nearly elliptical, the logarithmic, and the parabolic curves, allowing to each its due proportion of influence, we may estimate, from the comparison, which is the fittest form for an arch intended to support a road. And in general, whether the road be horizontal, or a little inclined, we may infer that an *ellipsis*, not differing much from a circle, is the best calculated to comply as much as possible with all the conditions, as represented by the following figure, which exhibits a view of the middle arch of

BLACKFRIAR'S BRIDGE.



A complete System of Theoretical and Practical Arithmetic. By Geo. G. Carey, 1 vol. 8vo. pp. 574. Hodgson and Co. London, 1824.

The science of arithmetic being the foundation of all accurate science, it is not surprising that so many works should have lately appeared upon that subject. The science of numbers has, at all times, not only been considered an amusing, but a very useful branch of study; it has therefore engaged the attention of the inquisitive part of mankind in all ages of the world. Hence this species of knowledge advanced with more rapid strides to the perfection at which we now find it, than any other, which it is possible to name. For, notwithstanding the number of books which have been published within the last thirty years upon this interesting subject, scarcely a single discovery has been made in the theory of numbers or even an improvement in their practical application to the purposes of the abstract or mixed mathematical sciences.

In commercial or mercantile affairs it is somewhat different. Improvements in the modes of calculation have certainly been made within the period we have mentioned; but these, we are persuaded, are much better known to the practical accountant, than to those who not only pretend to teach the whole science of Arithmetic, but publish works upon that subject, professing to be superior to all others, and to contain methods of computation hitherto unknown.

The taste which now prevails among all classes of society for accurate scientific knowledge, and the value of Arithmetic to those who are engaged in scientific as well as commercial pursuits, have led us to examine the present volume with some degree of care, in order to ascertain if it possesses any superiority over those which are already before the public.

The result of our examination is highly favourable both to the talents and industry of the author, who appears to us to be completely master of the subjects which he has introduced into the present volume; and to have treated them not only more fully than we have ever seen in works of this kind; but to have explained and illustrated his rules with greater care and clearness than any author we have perused on the science of Arithmetic.

The first part of Mr. Carey's work is devoted to the abstract part of arithmetic, and may be termed the theoretical part of the work.

This is followed by a number of very extensive and useful tables, relating to weights and measures. The fundamental rules are then applied to commercial and other computations, which are followed by the rules of Practice, Interest, Partnership, &c. But what appears to us to be not only the most original subjects in this volume, but the most valuable, (to those who already know the elements of arithmetic,) is the articles upon the Stocks, Public Funds, or Marine Insurance, Exchange, Compound Interest, and Annuities on Lives, with the tables on this last subject.

The subject of Marine Insurance is one which has not hitherto found its way into works on Arithmetic, at least in the regular and distinct manner it is treated of in the volume before us. We might say the same thing of the Stocks, and Annuities on Lives. These and Foreign Exchanges, are, however, very fully treated of by Mr. Carey, who appears to be well acquainted with all of them.

The work also contains a very neat and extensive table of the Logarithms of numbers, and an interesting and scientific article on Arithmetical Scales, in which the advantages and disadvantages of the Binary, Ternary, Quaternary, and other Scales, are very clearly and accurately pointed out.

On the whole, we have no hesitation in saying that this is the most extensive and comprehensive System of Arithmetic which has made its appearance for many years; and we have not the smallest doubt, but it will be found to be one of the most useful on that subject to those who may wish to make themselves master of Arithmetic.

ELECTRIC EFFECTS OF WATER AND OTHER LIQUIDS ON THE METALS, BY M. BECQUEREL.

A memoir on the electrical or galvanic effect of water and other liquids on the metals, was lately read before the Academy of Sciences at Paris, from which we make the following extract:

The author begins with showing the causes which have hitherto prevented him from observing some very feeble electrical effects, especially those that take place in the contact of water and metals. In his memoir he mentions the following appearances; when a capsule of wood or china is placed upon the upper plate of a very sensible condenser, and any liquid poured into it, the capsule immediately acquires a very perceptible conducting quality, sufficiently powerful to transmit the electricity which it receives to the plate upon which it rests; but as it sometimes happens, that this same capsule exercises a very weak electric action upon the metal, it may be destroyed by touching the lower plate with another capsule of the same nature. The apparatus being thus arranged, and after taking all the care necessary in such experiments, different metals are plunged into the water contained by the capsule; it is then seen that iron, zinc, lead, &c. becomes negatively electrified, whilst platina, gold, silver, &c. become positively electrified. Thus water, in its contact with the non-oxidizable metals, acts in the same manner as acids do in their contact with alkalies, when there is no chemical action.

M. Becquerel afterwards shows, that platina and gold, previously plunged into nitric acid, and afterwards washed, acquires more marked electrical effects in their contact with water. He also notices the remarks of Messrs Dulong and Thenard, upon the means of giving to fine platina wire the property of instantaneously communicating inflammability to detonating mixtures, which they did not before possess; the result of the comparison of these different effects is, that the modification or the arrangement which the particles acquire, by the immersion of platina wires in nitric acid, seems to be the cause which more promptly determines the combination of two gasses, and heighten the electrical properties of the metal.

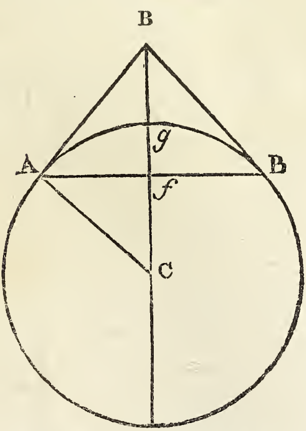
M. Becquerel repeated his experiments on the electric effects resulting from the contact of two metals with the same liquid; and found the effects to be perfectly similar. He therefore deduces a process from these experiments, for ascertaining which of any two metals exercises the strongest electric action upon a liquid.

He afterwards tried the electrical effects produced by the contact of certain flames and metals; the flames he submitted to trial, are those that arise from the burning of alcohol, from hydrogen gas, or from a sheet of paper. He placed upon the wooden capsule, which was set over the upper plate of the condenser, a wire or thin plate of platina, one of the extremities of which passed through the flame of one of the substances just mentioned; and if the metal attained a red heat, he found that it became negatively electrified, but if it did not, it became positively electrified. In both of these cases the flame has always a contrary electrical effect. When it is intended to collect the electricity acquired by the flame, a piece of damp wood is to be placed upon the capsule, which not taking fire serves as a conductor. Every other metal presents analogous effects; we may therefore conclude from these experiments, that when a piece of metal is placed in a flame supported by a current of hydrogen gas, it becomes either negatively or positively electrified, according as the temperature is more or less elevated. The author of this memoir fully discusses these phenomena, and finishes by stating the result of some experiments upon the electric effects that accompany combustion. He placed upon the capsule of wood already noticed, a sheet of paper rolled up: and as soon as set on fire, and the flame has communicated to the common reservoir, it is known, by means of the condenser, that the paper becomes positively electrified. In operating in the contrary manner, that is, by holding the paper in the hand, and making the flame touch a bit of damp wood placed upon the capsule, the flame become negatively electrified. We may therefore conclude from these experiments, that when a piece of paper burns, the paper becomes positively electrified, and the flame negatively electrified. The combustion of alcohol gives similar results.

SOLUTIONS OF QUESTIONS.

Quest. 42, (page 256) *answered by* C. N. F.

Let A C in the following figure,



represent the semi diameter of the earth $=$ 3978·875 miles, and B g, the elevation above the earth $=$ 2·5 miles. By 36 and 37 Euclid 3d Book $\sqrt{Bg \times (Bg + 2\,AC)}$ $(= \sqrt{2{\cdot}5 \times 7960{\cdot}25}) = 141{\cdot}0695 =$ A B.

But the triangles B A C and A f C are similar, therefore as B C : A C :: A C : fC, or 3981·375 : 3978·875 :: 3978·875 : 3976·369, and consequently $gf =$ A C $- fc = 2{\cdot}506$; now the convex surface of the segment of a sphere being equal to the circumference of the sphere multiplied by the height of the segment, it will be 25000 ($=$ the earth's circumference) $\times$ 2·506 $=$ 62650 square miles $=$ the area of the space in view at the given height.

This question was also answered by Mr. J. Johnston, *Elm-street, Gray's-inn-lane*, who makes the answer the same as the above; by Mr. J. Barr, who would have made it the same if he had taken the diameter of the Earth the *same;* by the Proposer, who makes it 46,876·6 square miles; and by Mr. J. Holroyd, *Oldham*, who makes it only 31,313·5 square miles. This last we suppose ought to have been multiplied by 2.

Quest. 43, *answered by* A. B. *(the Proposer.)*

Let $x =$ the height of the mercury in the tube, and $30-x =$ the inches of the tube now occupied by the air. Then as the elasticity of the air is inversely as the space it occupies; the elasticity was $=$ 28 inches, when it occupied 8 inches, and is now $=$ $(30-x) : 8 :: 28 : \frac{224}{30-x}$. But the mercury in the tube *plus* the elastic force of the air in the top of it, being a counterbalance to the pressure of the atmosphere, may be expressed by the column of mercury in the barometer. Therefore $x + \frac{224}{30-x} =$ 28, consequently $x^2 - 58x = -616$, or x $=$ 14 inches, the height required.

QUESTION FOR SOLUTION.

Quest. 46, *proposed by* W. J. *Lombard-street.*

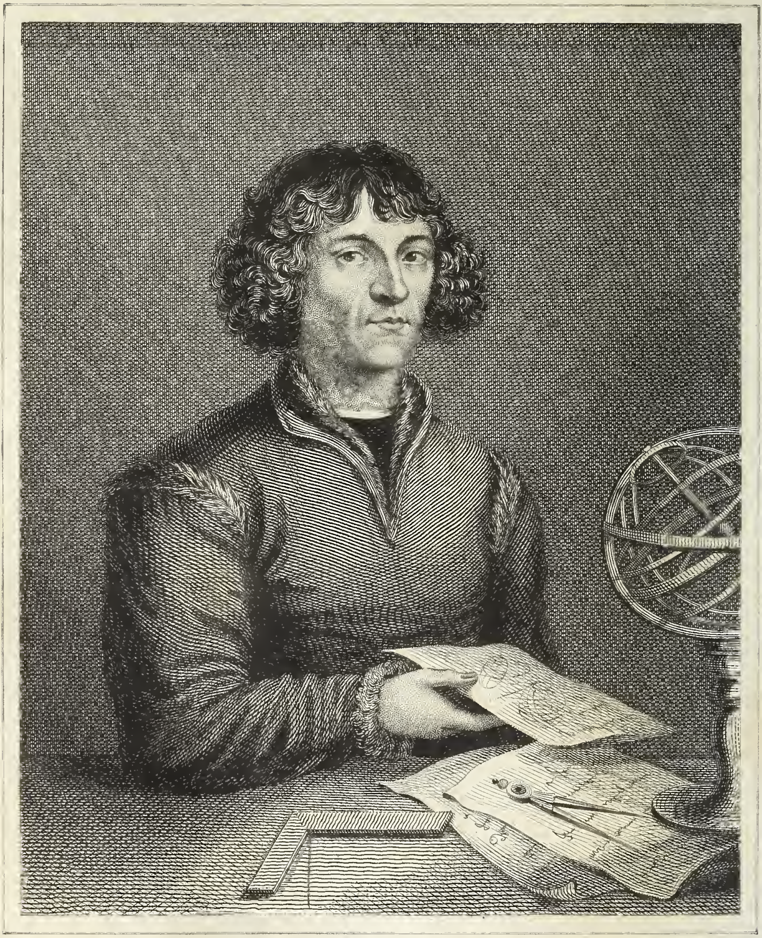
In what time will a sinking fund of 4 millions of pounds extinguish a debt of 600 millions of pounds, reckoning interest at $3\frac{1}{2}$ per cent.

Errata in a few of our early impressions.

For page 228, *read* 256.

In page 242, fig. 2, transpose the letters B and G; and A and F.

In page 304, col. 2, line 11, after water *read* enters.



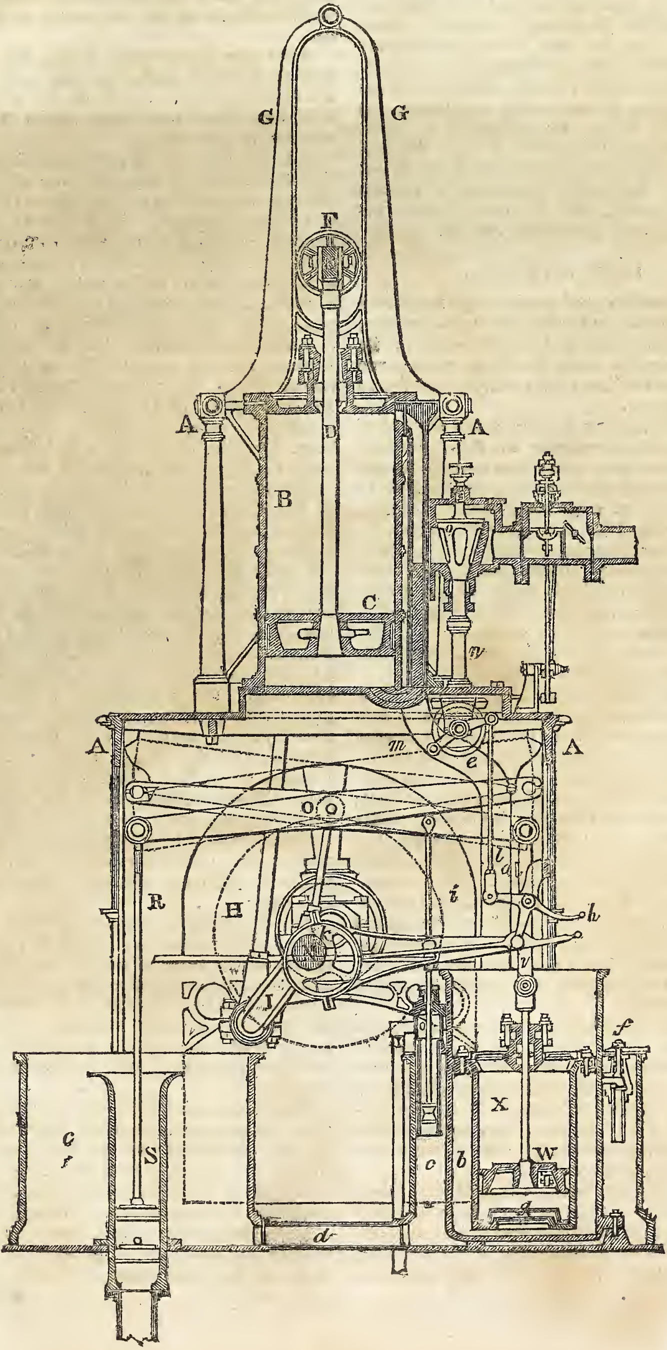
NICHOLAS COPERNICUS,

London, Published by Hodgson & Co. 10, Newgate St.

—1824—

PNEUMATICS.

LONGITUDINAL SECTION OF MAUDSLAY'S STEAM ENGINE.



STEAM ENGINE.

In treating of Pneumatics at page 289, we gave a description, and two different views of Mr. Maudslay's portable Steam Engine; and we now present our readers with a third view, or longitudinal section, of that instrument, which could not be got ready in time to accompany the others. In doing this it may be necessary to state, that the description given at page 290 and 291, as well as the capital letters employed to denote the several parts, apply to each of these views; but the small letters relate only to the preceding section.

STEAM NAVIGATION.

The possibility of employing steam as a moving power in the navigation of vessels, was known early in the last century; its practical application, however, on a large scale, has not been fully established above twenty years.

In 1698 Savery recommended the use of paddle-wheels, similar to those now so generally employed in steam vessels, though without in the remotest degree alluding to his engine as a prime mover; and it is probable that he intended to employ the force of men or animals working at a winch for that purpose. About forty years after the publication of this mode of propelling vessels, Mr. Jonathan Hulls obtained a patent for a vessel, in which the paddle-wheels were driven by an atmospheric engine of considerable power.

In describing his mode of producing a force sufficient for towing of vessels and other purposes, the ingenious patentee says, "In some convenient part of the tow-boat, there is placed a vessel about two-thirds full of water, with the top close shut; this vessel being kept boiling, rarefies the water into steam; this steam being conveyed through a large pipe into a cylindrical vessel, and there condensed, makes a vacuum, which causes the weight of the atmosphere to press on this vessel, and so presses down a piston that is fitted into this cylindrical vessel, in the same manner as in Mr. Newcomen's engine, with which he raises water by fire.

"It has been already demonstrated, that when the air is driven out of a vessel of thirty inches diameter, (which is but two feet and a half), the atmosphere presses on it to the weight of 4 tons 16 cwt. and upwards; when proper instruments for this work are applied to it, it must drive a vessel with great force."

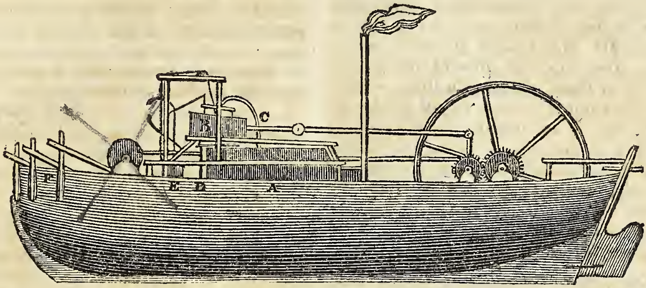
Mr. Hull's patent is dated 1736, and he employed a crank to produce a rotatory motion of his paddle-wheels, and this ingenious mode of converting a reciprocating into a rotatory motion, was afterwards recommended by the Abbé Arnal, Canon of Alais, in Lanquedoc, who, in 1781, proposed the crank for the purpose of turning paddle-wheels in the navigation of lighters.

After our countryman Hulls, the Marquis de Jouffroy unquestionably holds the most distinguished rank in the list of practical engineers, who have added to the value of this invention.

It is evident from an article published in the *Journal des Debats*, that in 1781 the Marquis constructed a steam boat at Lyons, of 140 feet in length. With this he made several successful experiments on the Soane, near that city. The events of the revolution, which broke out a few years afterwards, prevented M. de Jouffroy from prosecuting this undertaking, or reaping any advantage from it. On his return to France after a long exile, in 1796, he learned from the newspapers that M. de Blanc, an artist of Trevoux, had obtained a patent for the construction of a steam-boat, built probably from such information as he could procure relative to the experiments of the Marquis. The latter appealed to the government, which was then too much occupied with public affairs to attend to those of individuals. Meanwhile Fulton, who had gained the same information, and was making similar experiments near the Isle des Cygnes, alarmed M. de Blanc, who knew that he had much more to fear from the influence and mechanical skill of an Anglo-American, than from that of an emigrant. He accordingly alleged his patent right, and requested the stoppage of Mr. Fulton's works, who returned for answer, that his essays could not affect France, as he had no intention to set up a practical competition upon the rivers of that country, but should soon return to America, which he actually did, and commenced the erection of those engines, to which he has since laid claim as exclusive inventor.

Shortly after the first experiments were made by the Marquis de Jouffroy, a gentleman of the name of Miller, who resided at Dalswinton, published a work, in which he described the application of wheels to the working of triple vessels on canals; and in 1794 he completed a model of a boat on this construction, impelled by a steam engine.

From this period till 1801, but little progress appears to have been made in this species of navigation; in that year Mr. Symington, who had been employed in the construction of Miller's vessel, tried a boat propelled by steam on the Forth-and-Clyde Inland Navigation: this, however, was shortly laid aside, on account of the injury with which it threatened the banks of the canal, from the violent agitation produced by the paddle-wheels. The following figure exhibits a representation of the boat.



A is the boiler, B the cylinder, C the piston, D the condensation pipe, E the air pump, and F are stampers for breaking ice.

The first really practicable, and we may add profitable attempt at steam navigation in Europe, appears to have been made on the Clyde in the year 1812. This was a vessel for the conveyance of passengers, with an engine of only three horses' power, and which was of considerable draught. On account, however, of the numerous shallows in our rivers, it has been found advisable to construct the vessels employed in this species of navigation, so as to draw as little water as possible.

Mr. Maudslay has lately constructed a large engine for a steam boat, invented by Mr. Brunel, which has two cylinders acting alternately upon different cranks, formed upon the same axis at right angles to each other, so that the motion is continued without the action of a fly-wheel. In this engine, one boiler is placed between the two cylinders, and one air-pump and condenser exhaust them both; so that by these means an engine of considerable power is contained in the smallest possible space.

We shall now briefly notice the labours of our Trans-atlantic brethren in this important branch of naval engineering. Profiting by the hints thrown out both by the Marquis de Jouffroy and Mr. Miller, Fulton, who had also seen Symington's boat, ordered an engine, as represented above, capable of propelling a vessel, to be constructed by Messrs. Boulton and Watt. This was sent out to America, and embarked on Hudson's river in 1807; and such was the ardour of the Americans in support of this apparently new discovery, that the immense rivers of the new world, whose great width gave them considerable advantages over the canals and narrower streams of Europe, were soon regularly navigated by these vessels.

The city of New York alone possesses eight steam boats, for commerce and passengers. One of those on the Mississippi passes two thousand miles in twenty-one days, and this too against the current which is perpetually running down. This boat is 126 feet in length, and carries 460 tons at a very shallow draft of water, and conveys from New Orleans, whole ships' cargoes into the interior of the country, as well as passengers.

The usual mode of applying this extraordinary power to the propelling of vessels, has been by means of the *paddle*, which is a series of revolving oars on one axis.

This possesses the great advantage of admitting safely of any increase of velocity, without endangering the connection of their parts; on the other hand, an alternate motion can hardly be produced of sufficient rapidity, without having the effect of shaking itself to pieces.

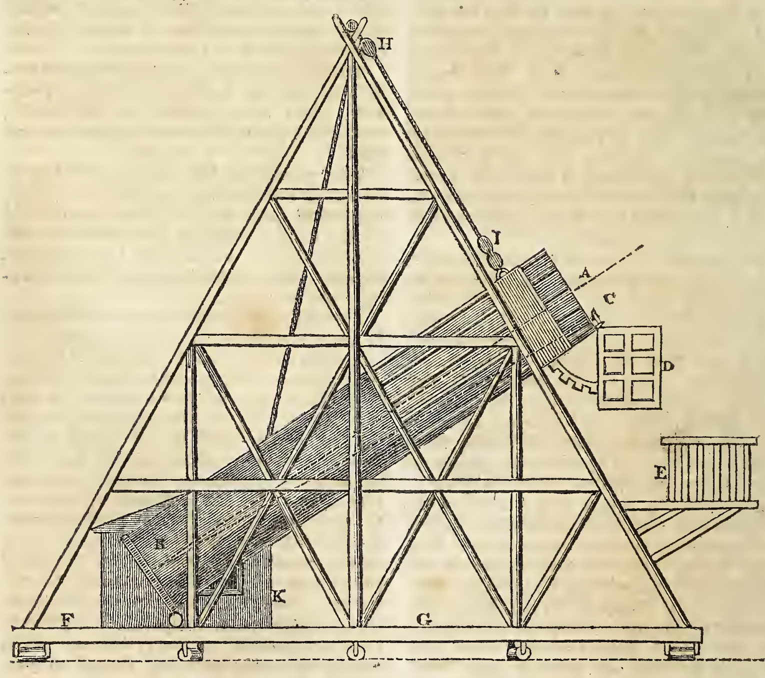
The increase of velocity is not limited as in the common oar, where the application of human power, and the difficulty of quick re-percussion, obliges us, where great velocity is wanted, to have recourse to oars of great length, for the revolution of the paddle wheel may be as rapid as we please, or its diameter may be increased in any degree, and by this last means the loss arising from the obliquity of action at the beginning and end of the stroke may be lessened, and the effect of back-water on the wheel diminished by the increased centrifugal force communicated to the water. Here, therefore, is a rich field for the investigation of the mechanical philosopher, or scientific engineer, but one which we cannot enter into very deeply at present.

We may however remark, that though velocity in the propeller or oar be desirable, yet it has its limits; for, in the first place, time must be given for the water to fall in after the oar or paddle, before a new stroke be given, and therefore the paddles or oars should be as few as possible. A propeller of great radius will also be found inconvenient, by occupying too much space. The water should enter and be discharged from the paddle, as nearly as possible in a *tangent* to the circle; and where *waves* occur, they should be prevented from rising against, and burying the paddle. Where the vessel works both with sails and paddles, the means of equalizing the action of the paddles, as the vessel heels, must be employed. For in heavy gales of contrary wind, the machinery will scarcely be able to force the vessel against it, and the mode of beating to windward with sails will be found of greater importance. The propellers will destroy the leeway; and we know that if the vessel can carry sail, she may, in such cases, run on the oblique course with a greater velocity than that of the wind.

OPTICS.

SIR W. HERSCHEL'S LARGE TELESCOPE.

The Newtonian telescopes, which had for a long time been thrown into the shade by the fine Gregorian ones constructed by Mr. Short, were revived, towards the end of the last century, by Sir W. Herschel. His telescope of forty feet will long remain a splendid example of royal munificence, and of the zeal and ingenuity of its inventor. We shall now attempt to convey an idea of its appearance and construction by means of the following figure.



A B C is the path of a ray of light reflected by the mirror at B to the eye-glass C. D a chair in which the observer sits. E a moveable gallery on which several persons may stand. F G a smooth surface on which the bottom of the telescope is made to roll along, while its opening is raised or depressed by the pullies at H and I. K one of two rooms for the accommodation of the observer's assistants.

It rests on a foundation of two concentric circular brick walls, the outermost of which is forty-two feet in diameter, and the innermost twenty-one feet. These walls are two feet six inches deep under ground; two feet three inches broad at the bottom, and one foot two inches at the top, and they are capped with paving stones, about twelve and three-fourth inches broad, and about three inches thick. Upon these two walls, which were made uniform on the surface, and horizontal, with the greatest care, rests the bottom frame of the whole apparatus, which moves upon twenty concentric rollers, and is always moveable upon a pivot, which gives a horizontal motion to the whole apparatus. The length of the ladders is forty-nine feet two inches, and the flats and rounds are all made of solid English split oak. The two outside divisions of the ladders serve for mounting into the gallery. The middle top cross beam rests on the angle made by the crossing of the two sets of ladders. There is a small staircase, by which we may ascend into the gallery without being obliged to go up the ladders, and as the gallery is strong enough to hold a company of several persons, and can afterwards be drawn up to any altitude, observations may be made with the greatest facility and conveniency.

The great tube, though of a very simple form, was constructed with much difficulty. It is thirty-nine feet four inches long, four feet ten inches in diameter, and every part of it is made of rolled or sheet iron, joined together without rivets, by a kind of sealing used in the manufacture of iron funnels for stoves. The whole outside was thus put together in all its length and breadth, so as to make one sheet of nearly forty feet long, and fifteen feet four inches broad. Each sheet of iron was three feet ten inches long, and about 23½ inches broad. Their thickness was less than the 36th part of an inch, and a square foot weighed about fourteen ounces. Had the tube been made of wood, its weight would have exceeded that of the iron one at least 3000 lbs.

The metal of the great mirror is 49½ inches in diameter, but on the rim there is an offset of three-fourths of an inch broad, and one inch deep, which reduces the concave face of it to a diameter of 48 inches of polished surface. The thickness, which is uniform throughout, is about 3½ inches, and its weight, when newly cast, was 2118 lbs. of which it must have lost a small quantity in polishing. In order to preserve the speculum from damp, a flat cover of tin was soldered on a rim of iron, about 1¾th broad, and 1-8th thick, the diameter of which is equal to that of the iron ring which holds the speculum. On the flat part of the rim, some close-grained cloth, of an equal breadth with the rim, is cemented all round, so that the rim of the cover, when put over the speculum, fits closely to the edge of the iron ring.

The method of observing with this telescope, is what Sir W. Herschel calls the front view, and for this purpose there is a convenient seat D fixed to the end of the tube, in which the observer sits with his back towards the object he views. The seat is moveable from the height of one foot seven inches to two feet seven inches, partly for the accommodation of different observers, but chiefly for the alteration required at different altitudes. This seat is brought to a horizontal position by turning a handle attached to a bar, carrying two pinions, which work in two strong toothed quadrants of iron at the sides of the seat. The focus of the great speculum is brought down by its proper adjustment to within four inches of the lower side of the mouth of the tube, and comes forward into the air, and by this arrangement there is room for that part of the head which is above the eye, not to interfere greatly with the rays that pass from the object to the mirror; the aperture of the speculum being four feet, while the diameter of the tube is four feet ten inches.

A slider on an adjustable foundation is fixed at the mouth of the telescope, so as to be directed to the centre of the speculum. It carries a brass tube, into which all the single eye-glasses are made to slide. When they are nearly brought to the focus, a milled head under the end of the tube turns a bar, the motion of which adjusts them completely, so that as there is no small speculum, the eye-glasses are applied immediately to magnify the inverted image in the focus of the great speculum.

From the mouth of the telescope a speaking pipe descends to the bottom of the tube, when it divides into two branches, one of which enables the observer to communicate with his assistant in the observatory K, and the other with the workman in another room, who gives the instrument all its movements.

A sidereal time-piece is placed in the observatory, and close to it a polar distance-piece, which may be made to show polar distances, declination, or altitude, by setting it differently. The time and polar distance-pieces are placed in such a manner, that the assistants sit before them at a table, the speaking pipe rising between them, and in this manner observations may be very conveniently made.

This splendid instrument magnifies above 6000 times, and Sir William has sometimes employed a power of 6450 for the fixed stars. These high powers are obtained merely by using small double convex lenses for eye-glasses. Some of these, ground and polished with the utmost care, are so small as *one-fiftieth of an inch* in focal length. The existence of such minute lenses we should have thought incredible, had we not been assured of the fact, and found that others had of them made by the same ingenious artist, (the late Mr. Shuttleworth,) who ground them for Sir William Herschel.

NEW REFLECTING TELESCOPE BY DR. BREWSTER.

We believe it is generally admitted by every person who has had much experience in the construction and use of reflecting telescopes, that the Newtonian form is decidedly the best. Its construction is so simple, and it is so little liable to derangement from accidental causes, that for popular use, on a small scale, it is superior to the Gregorian one, while, for instruments of great size, it is the only form that is practicable. But even when we consider it in a scientific point of view, it has the advantage of the Gregorian form. It is more easy to give a perfect figure to an uniform circular piece of metal than to a perforated disc;—the spherical aberration is less, in so far as it is not increased by a second spherical mirror;—and the quantity of light reflected from the oblique small speculum is decidedly greater than when it is reflected at a vertical incidence.

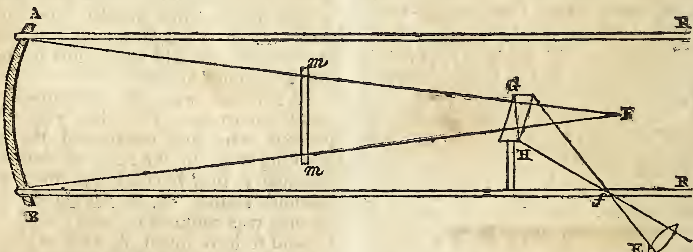
If we could dispense with the use of the small specula in telescopes of moderate length, by inclining the great speculum, and using an oblique, and consequently a distorted reflexion, as proposed first by Le Maire, we should consider the Newtonian telescope as perfect; and on a large scale, or when the instrument exceeds twenty feet, it has undoubtedly this character, as nothing can be more simple than to magnify by a single eye-glass the image formed by a single speculum.

As the *front view* is quite impracticable, and indeed has never been attempted in instruments of a small size, it becomes of great practical consequence to remove as much as possible the evils which arise from the use of a small speculum. These evils may be thus enumerated :

1. If we suppose the light reflected by the large speculum to amount to 10000 rays, then the light reflected by a well polished plane speculum will not exceed 6666 at a vertical incidence, and probably not above 6800 at an incidence of 45°; consequently 3100 rays out of 10,000 are lost by the use of the plane speculum.

2. Besides this great loss of light, we have to encounter all the errors of a second reflexion, arising from imperfection of figure, and also from imperfections of surface, as it is universally admitted that a surface of glass is much superior to a metallic surface; and Newton has himself remarked, "that every irregularity in a reflecting superficies makes the rays stray *five or six times* more out of their due course than the like irregularities in a refracting one.

The construction by which Dr. Brewster proposes to remedy these disadvantages is shown in the following figure,



where A B is the speculum, reflecting the parallel rays R A, R B, to a focus at F. The cone of rays A F B is intercepted by an achromatic prism G H, which refracts them to foci at *f*, where a distinct image is formed in the anterior focus of the eye-glass E, by which it is magnified. The compound prism G H being composed of a prism of crown glass, and a prism of flint glass H, united by a cement of a mean refractive power, the loss of light sustained by the pencil in its transmission through the two, will not exceed 600 rays out of the 10,000, as the light transmitted through a lens of glass is 9485 out of the 10,000 incident rays. Hence the light lost by transmission through the prism is not *one-fifth* part of the light lost by reflexion; and the errors of reflexion arising from defect of surface and of figure are also incomparably less. As the refracting angle of the prism G will require to be larger, in order to produce a given deviation F H *f*, when it is opposed by the refraction of the flint-glass prism H, we may place the correcting prism H nearer the focus *f*, and make it of crown glass; or it might even be placed at *h*, beyond the focus, and in contact with the lens E. If this should be found advantageous, the prism and the lens might be formed out of one piece of glass, or a single hemisphere of glass might be used, the eye-hole being placed at such a point of the hemispherical surface, as to obtain a variable prism of the required angle united with a plano-convex lens.

As Dr. Maskelyne found that the Greenwich Newtonian telescope was greatly improved by inclining the speculum, or its axis, about 2½° to the axis of the tube, it follows, that it performed best with oblique pencils in a certain direction. Before fitting up this telescope, therefore, or indeed any Newtonion telescope, it should be ascertained, by turning the speculum in its cell and giving its axis various degrees of obliquity, whether or not its performance is improved. If this is found to be the case, and that the angle of inclination is $2\frac{1}{2}°$, we shall then require a less angle in the prism G, as part of the deviation of the pencil to the side of the tube is already produced by the new position of the axis of the speculum.

It is obvious that any rays incident on the prism G H, parallel to the tube, will be refracted upon the side of the tube, and will have no effect upon the image; but if they should be thought injurious, we have only to place an opaque screen, of the same size as G H and its arm, somewhere between G H and the mouth of the tube, so as not to interfere with the cone of refracted rays G H *f*.

In viewing eclipses of the sun, or the lunar disc, or any other celestial phenomenon, where there is either too much light, or more than is necessary, a telescope may be fitted up to permit more than one person to see through it at the same time, by allowing a portion of the cone of rays to be refracted through another prism to an eye-glass at the opposite side of the tube, or even by having four prisms refracting a fourth part of the cone to each of the four sides of the tube. The same effect might be produced in the common Newtonian telescope, by using a pyramidal small speculum with the planes meeting at a vertex placed in the centre of the cone of rays, and inclined to one another at angles of 90°, and to the axis of the telescope at angles of 45°.

CHEMISTRY.

OF THE METALS.

The metals are the next class of bodies which fall to be described in the order which we have laid down, for treating of the various substances to be noticed in this part of the present work.

We shall therefore now enter upon the description of these brilliant bodies so useful to society; which so highly influence public and individual prosperity, not only by their real properties, but by the ideal value attached to them; which have on the one hand rendered such eminent services to humanity, and on the other produced so many evils; which at the same time mark the industry of nations, and add to the improvement of human reason, while they so often become the instruments, and almost the cause, of the depravation, the misery, and all the evils which afflict mankind. There are no productions of nature which excite a higher degree of interest in their study, or which have given rise to so many discoveries: there are not, consequently, any substances which deserve to be treated more fully, or with greater care.

The multiplied uses to which the metals are applicable, do not constitute the only reason why they should be described with accuracy, and studied with attention. The vast influence which they have had on the progress of chemistry, the discoveries which relate to them, particularly in modern times, and the perfection which they have added to human reason, render them of the greatest consequence to those who cultivate natural philosophy. On the properties of these bodies depend the mariners' compass, the arts of printing, of navigation and astronomy, and every other science which are most truly honourable to the genius of man. There is, in truth, no art which can be carried on without the metals. They are the first movers and primary instruments of almost every workshop. There is scarcely a single circumstance of life in which we do not derive continual services, or in which we are not subjected to dangers from their energy. The metals are friends which serve us, and which it is desirable we should always have near us; or they are enemies pressed into our employ, which it is consequently of importance that we should know how to subdue, and sometimes to coerce.

So sensible were the ancients of their great importance, that they raised those persons who first discovered the art of working them to the rank of deities. In Chemistry, they have always filled a conspicuous station: at one period the whole science was confined to them; and it may be said to have owed its very existence to a rage for making and transmuting metals.

One of the most conspicuous properties of the metals is a particular brilliancy which they possess, and which has been called the *metallic lustre*. There are other bodies indeed (*mica* for instance) which apparently possess this peculiar lustre; but in them it is confined to the surface, and accordingly disappears when they are scratched; whereas it pervades every part of the metals. This lustre is occasioned by their reflecting much more light than any other bodies; a property which seems to depend partly on the closeness of their texture. This renders them peculiarly proper for mirrors, of which they always form the basis.

They are perfectly opaque, or impervious to light, even after they have been reduced to very thin plates. Silver leaf, for instance, $\frac{1}{160000}$ of an inch thick, does not permit the smallest ray of light to pass through it. Gold, however, when very thin, is not absolutely opaque; for gold leaf $\frac{1}{280000}$ of an inch thick, when held between the eye and the light, appears of a lively green, and must therefore, as Newton first remarked, transmit the green coloured rays. It is not improbable that all other metals, as the same philosopher supposed, would also transmit light, if they could be reduced to a sufficient degree of thinness. It is to this opacity that a part of the excellence of the metals, as mirrors, is owing; their brilliancy alone would not qualify them for that purpose.

Most of them may be melted by the application of heat, and even then still retain their opacity. This property enables us to cast them in moulds, and then to give them any shape we please. In this manner, many elegant iron utensils are formed. Different metals differ exceedingly from each other in their fusibility. Mercury is so very fusible, that it is always fluid at the ordinary temperature of the atmosphere; while other metals, as platinum, cannot be melted except by the most violent heat which it is possible to produce.

In general, their specific gravity is much greater than that of any other body at present known. Potassium, one of the lighest of them, is, however, lighter than water; and the specific gravity of platinum, the heaviest of all the metals, is 23. This great density, no doubt, contributes considerably to the reflection of that great quantity of light which constitutes the metallic lustre.

They are the best conductors of electricity of all the bodies hitherto tried.

None of the metals are very hard; but some of them may be hardened by art to such a degree, as to exceed the hardness of almost all other bodies. Hence the numerous cutting instruments which the moderns make of steel, and which the ancients made of a combination of copper and tin.

The elasticity of the malleable metals depends upon their hardness; and it may be increased by the same process by which their hardness is increased. Thus the steel of which the balance springs of watches is made is almost perfectly elastic, though iron in its natural state possesses but little elasticity.

But one of their most important properties is *malleability*, by which is meant the capacity of being extended and flattened when struck with a hammer. This property, which is peculiar to metals, enables us to give the metallic body any form we think proper, and thus renders it easy for us to convert them into the various instruments for which we have occasion. All metals do not possess this property; but almost all those which were known to the ancients have it. Heat increases this property considerably. Metals become harder and denser by being hammered.

Another property, which is also wanting in many of the metals, is *ductility;* by which we mean the capacity of being drawn out into wire, by being forced through holes of various diameters.

Ductility depends, in some measure, on another property which metals possess, namely, *tenacity;* by which is meant the power which a metallic wire of a given diameter has of resisting, without breaking, the action of a weight suspended from its extremity. Metals differ exceedingly from each other in their tenacity. An iron wire, for instance, $\frac{1}{10}$ of an inch in diameter, will support, without breaking, about 500 lb. weight; whereas a lead wire, of the same diameter, will not support above 29 lb.

When metals are exposed to the action of heat and air, most of them lose their lustre, and are gradually converted into earthy-like powders of different colours and properties, according to the metal and the degree of heat employed. Several of them even take fire when exposed to a strong heat; and after combustion, the residuum is found to be the very same earthy-like substance.

All metals, even the few that resist the action of heat and air, undergo a similar change, when exposed to acids, especially the sulphuric, the nitric, and the muriatic, or a mixture of the two last. All metals, by these means, may be converted into powders, which have no resemblance to the metals from which they were obtained. These powders were formerly called *calces;* but at present they are better known by the name of *oxides*. They are of various colours, according to the metal and the treatment, and are frequently manufactured in large quantities to serve as paints.

When these oxides are mixed with charcoal powder, and heated in a crucible, they lose their earthy appearance, and are changed again into the metals from which they were produced. Oil, tallow, hydrogen gas, and other combustible bodies, may be often substituted for charcoal. By this operation, which is called the *reduction* of the oxides, the combustible is diminished, and, indeed, undergoes the very same change as when it is burned.

No metal can be converted into an oxide, except some substance be present which contains oxygen; and, during the oxydizement, a portion of that oxygen disappears.

There are some metallic oxides which can be reduced by the application of heat in close vessels. Now, whenever they are reduced in that manner, they yield oxygen gas: and the weight of the oxygen, together with that of the metal obtained, is equal to the weight of the original oxide. Thus, when the oxide of mercury is heated in a retort, to which a pneumatic apparatus is attached, to the temperature of 1000°, it is converted into pure mercury; and, at the same time, a quantity of oxygen separates from it in a gaseous form. The weights of the metal and the oxygen gas are together equal to that of the oxide; the calx of mercury, therefore, must be composed of mercury and oxygen only. Its calcination is merely the act of its uniting with oxygen. Gold, platinum, silver, nickel, and even lead, may be reduced in the same way, and with the same evolution of oxygen gas. Several other oxides may be brought nearer the metallic state, though they cannot be completely reduced by heat, and this approach is accompanied by the escape of oxygen gas. Manganese, zinc, and probably also iron, are in this predicament.

All the oxides are reduced by means of combustible bodies, and, during the com bustion, the combustible unites to oxygen. This is the reason that charcoal-powder is so efficacious in reducing them; and if they are mixed with it, and heated in a proper vessel furnished with a pneumatic apparatus, it will be easy to discover what passes. During the reduction, a great deal of carbonic acid and carbonic oxide comes over. These, together with the metal, are equal to the weight of the oxide and the charcoal: they must therefore contain all the ingredients; and we know that they are composed of carbon and oxygen. Therefore, during the process, the oxygen of the oxide combines with the charcoal, and the metal remains behind. In the same manner, when oxide of iron is heated sufficiently, in contact with hydrogen, the iron is reduced, and water is formed, as was first ascertained by the experiments of Dr. Priestly.

It therefore cannot be doubted, that all the metallic calces are composed of the entire metals combined with oxygen; and that calcination, like combustion, is merely the act of this combination. All metals, then, in the present state of Chemistry, must be considered as simple substances; for they have never yet been decompounded.

The words *calx* and *calcination* being evidently improper, because they convey false ideas, the words *oxide* and *oxidizement*, which were invented by the French Chemists, are substituted for them. A metallic *oxide* significes a metal united with oxygen; and *oxidizement* implies the act of that union.

Metals, then, are all capable of combining with oxygen; and this combination is sometimes accompanied by combustion, and sometimes not. The new compounds formed are called *metallic oxides*, and in some cases *metallic acids*. Like the two last classes of bodies, they are capable of combining with different doses of oxygen, and of forming different species of oxides or acids. These were formerly distinguished from each other by their colour. One of the oxides of iron, for instance, was called *black oxide*, another was termed *red oxide*; but it is now known that the same oxide is capable of assuming different colours, according to circumstances. The mode of naming them from their colour, therefore, wants precision, and is apt to mislead; especially as there occur different examples of two distinct oxides of the same metal having the same colour.

As it is absolutely necessary to be able to distinguish the different oxides of the same metal from each other with perfect precision, and as the present chemical nomenclature is defective in this respect, we shall adopt the nomenclature of Dr. Thomson, and distinguish them from each other, by prefixing to the word *oxide* the first syllable of the Greek ordinal numerals. Thus the *protoxide* of a metal will be employed to denote the metal combined with a minimum of oxygen, or the *first oxide* which the metal is capable of forming; *deutoxide* to denote the second oxide of a metal, or the metal combined with two doses of oxygen;* and when a metal has combined with as much oxygen as possible, the term *peroxide* will be employed to signify that the metal is thoroughly oxidized.

We shall therefore employ the term *oxide* to denote the combination of metals with oxygen in general; the terms *protoxide* and *peroxide* to denote the minimum and maximum of oxidizement; and the terms *deutoxide*, *tritoxide*, &c. to denote all the intermediate states which are capable of being formed.

Metals are capable of combining with the simple combustibles. The compounds thus formed are denoted by the simple combustible which enters into the combination, with the termination *uret* added to it. Thus the combination of a metal with sulphur, phosphorus, or carbon, is called the *sulphuret*, *phosphuret*, or *carburet* of the metal. The compounds formed by the metals with the three combustibles just mentioned are usually solid; but when hydrogen unites with them, it still retains the elastic state. These solutions of metals in hydrogen have been but slightly examined. They are usually distinguished by an epithet, indicating the metal, prefixed to the word hydrogen, as arsenical hydrogen.

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* The same explanation will apply to *tritoxide*, (third oxide), *tetoxide* (fourth oxide), &c. whenever they become necessary.

The metals in general unite very readily with one another, and form compounds, some of which are extremely useful in the manufacture of instruments and utensils. Thus *pewter* is a compound of lead and tin; *brass*, a compound of copper and zinc; *bell-metal*, a compound of copper and tin. These metallic compounds are called by Chemists *alloys*, except when one of the combining metals is *mercury*. In that case, the compound is called an *amalgam*. Thus the compound of mercury and gold is called the *amalgam of gold*.

When no other bodies were considered as metals but those which possess ductility, and when their number was confined to six or seven, it was not necessary to seek after many properties, nor to establish any method for distinguishing and ascertaining each of these bodies. The notion of forming a classification must have scarcely occupied the attention of chemists.

ASTRONOMY.

OF ECLIPSES.

Of all the various phenomena of the heavens there are none which have created so much curiosity, excited so much interest, or caused so great terror throughout the world, as eclipses of the sun and moon; and to those who are unacquainted with the principles of astronomy there is nothing perhaps which appears more extraordinary than the accuracy with which they can be predicted.

In the earlier ages of the world, before science had enlightened the minds of men, appearances of this kind were generally regarded as alarming deviations from the established laws of nature; and but few, even among philosophers themselves, were able to account for these extraordinary appearances. At length, when men began to apply themselves to observations, and when the motions of the celestial bodies were better understood, these phenomena were not only found to depend upon a regular cause, but to admit of a natural and easy solution. There are, however, nations that still entertain the most superstitious notions respecting eclipses, particularly the Mexicans and Chinese.

Thus when the infant moon her circling sphere
Wheels o'er the sun's broad disk, her shadow falls
On earth's fair bosom; darkness chills the fields,
And dreary night invests the face of heaven.
Reflected from the lake full many a star
Glimmers with feeble languour. India's sons
Affrighted in wild tumult rend the air.
Before his idol god with barb'rous shriek
The Brachman * falls: when soon the eye of day
Darts his all-cheering radiance, from the gloom
Emerging. Joy invades the wond'ring crowd,
And acclamation rushes from the tongues
Of thousands, that around their blazing pile
Riot in antic dance and dissonant song. ZOUCH.

Many instances are to be found, not only in ancient, but even in comparatively modern history, where the superstition of the times has continued to connect the records of eclipses with the details of some remarkable event, which either happens soon after or during their continuance. But these details being foreign to the nature of the present work, we shall proceed to give an account of the causes, and various kinds of eclipses of the sun and moon.

As every planet belonging to the solar system, both primary and secondary, derives its light from the sun, it must cast a shadow towards that part of the heavens which is opposite to the sun. This shadow is of course nothing but a privation of light in the space hid from the sun by the opaque body, and will always be proportionate to the relative magnitudes of the sun and planet. If the sun and planet were both of the same size, the form of the shadow cast by the planet would be that of a cylinder, the diameter of which would be the same as that of the sun or planet, and it would never converge to a point. If the planet were larger than the sun, the shadow would continue to spread or diverge; but as the sun is much larger than the greatest of the planets, the shadows cast by any one of these bodies must converge to a point, the distance of which from the planet will be proportionate to the size and distance of the planet from the sun. The magnitude of the sun is such that the shadow cast by each of the primary planets always converges to a point before it reaches any other planet; so that not one of the primary planets can eclipse another. The shadow of any planet which is accompanied by satellites may, on certain occasions, eclipse these satellites; but it is not long enough to eclipse any other body. The shadow of a satellite or moon may also, on certain occasions, fall on the primary and eclipse it.

Eclipses of the sun and moon happen when the moon is near her nodes, that is, when she is either in the plane of the ecliptic or very near it. Those of the sun happen only at new moon, or when the moon is in conjunction with the sun; whilst those of the moon happen at the time of *full moon*, or when the moon is in opposition to the sun. The sun, earth, and moon, must therefore always be nearly in the same straight line at the time of an eclipse; and conversely, when these three bodies are nearly in a straight line, an eclipse must take place. Hence it is evident, that an eclipse happens in consequence of one of the two opaque bodies, the earth and the moon, being so placed as to prevent the

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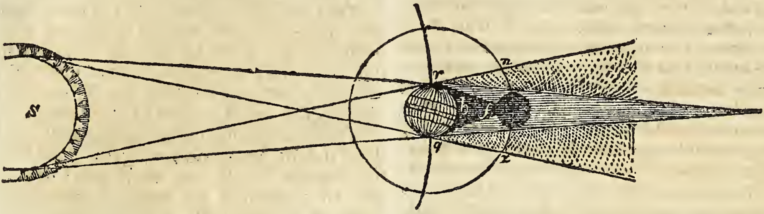
* Although the Chinese perform the most ridiculous and superstitious ceremonies during the time of an eclipse, yet they can calculate them with the greatest precision.

sun's light from falling on the other.—See the following figure, which represents the moon passing through the dark shadow of the earth, as she moves in her orbit *n z*, while the earth moves in the ecliptic *r q*.



The interposition of t e moon between the sun and the earth produces an eclipse of the sun; and the interposition of the earth between the moon and the sun, so that its shadow falls on the moon, produces an eclipse of the moon. On these principles the whole phenomena of eclipses depend, and admit of complete explanation.

If the moon's orbit were coincident with the plane of the ecliptic, the moon's shadow would fall upon the earth, and occasion a *central eclipse* of the sun at every conjunction, or new moon; whilst the earth's shadow would fall on the moon, and occasion a total eclipse of that body at every opposition or full moon. For as the moon would then always move in the ecliptic, the centres of the sun, earth, and moon, would all be in the same straight line at both of these times. But the moon's orbit is inclined to the ecliptic, and forms with it an angle of about 5° 10′; and, therefore, the moon is never in the ecliptic except when she is in one of her *nodes:* hence, there may be a considerable number of conjunctions and oppositions of the sun and moon without any eclipse taking place.

The moon is always at some distance from the ecliptic, except when she is in one of her *nodes;* and this distance is called her *latitude*, which is north or south, according as the moon is on the north or south side of the ecliptic. Now if the moon has any latitude, there cannot be a *central* eclipse, for this can only happen when the moon is in one of her nodes at the moment of conjunction, which is very seldom the case; and, of course, very few central eclipses of the sun have taken place since the creation of the world.* But the section of the earth's shadow (through which the moon passes when she is eclipsed) being much larger than the disc of the moon, the moon may be *totally* eclipsed, although she be at some distance from her node at the time of opposition; but its duration will be the greater the nearer she is to the node. An eclipse of the *sun* may also happen, although the moon be at some distance from her node at the time of conjunction; but its form, as well as its duration, depend very much upon that distance. This circumstance has occasioned the division of eclipses into central, total, annular, and partial.

As the meaning of these terms must be obvious to the reader, it is almost unnecessary to give an explanation of them.

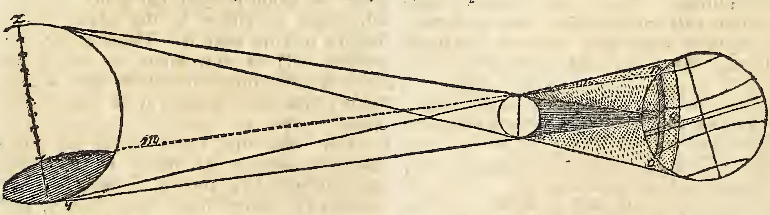
A central eclipse, is that in which the centre of the shadow falls on the centre of the body which is eclipsed.

A total eclipse is the obscuration of the whole body eclipsed.

An annular eclipse is that in which the whole of the body eclipsed is hid, except a ring round its edge, which remains luminous.

A partial eclipse is that in which part of the eclipsed body is hid from view.

The following figure represents a partial eclipse of the sun, which will be visible to that tract of the earth marked *n p o*, the line *m n* marks the greatest obscuration.



If the distance be very small, the eclipse will be the greater and continue the longer; but no eclipse of the sun can be either *central* or total, except the moon be in the very node at the time of conjunction. But should she be in this situation, when she is

* One of the most remarkable eclipses of this kind which has ever happened, was visible in Britain and several other countries, on the 7th of September, 1820.

at her least distance from the earth, and the earth, at the same time, at its least distance from the sun, then the eclipse will not only be central but *total*, and continue so for a few minutes. But if the moon happens to be at her greatest distance from the earth, and the earth at its greatest distance from the sun, the eclipse will be annular, or a small space round the sun's centre only will be hid from view, and a bright lucid ring round his edge will remain visible.

If the moon be less than 17⅓ degrees from either node at the time of conjunction, her shadow will fall more or less upon the earth, according as she is more or less within this limit; and, of course, the sun will suffer a partial eclipse. And if she be less than 12½ degrees from either node at the time of opposition, she will pass through more or less of the earth's shadow, according as she is more or less within these lines, and of course she will suffer an eclipse.

As these limits form but a small part of the moon's orbit, which is 360 degrees, eclipses happen but seldom; however, in no year can there be fewer than two, and there may be seven of the sun and moon together—but taking one year with another, there are about four each year. But as the sun and moon spend as much time below the horizon of any place as above it, half the number of the eclipses will be *invisible* at any particular place, and consequently there will be only *two* eclipses visible in a year at that place, the one of the sun and the other of the moon.*

Every eclipse, whether of the sun or moon, is *visible* at some place of the earth's surface, and invisible at others; for the rational horizon of every place divides both the earth and heavens into two equal portions or hemispheres; and as no celestial body can be seen except it be above the spectator's horizon, it follows that any eclipse which is visible in the one hemisphere cannot be visible in the other, because the body which is eclipsed is below the horizon of that other. If a lunar eclipse, for examlpe, happens at any hour of the night, between the time of sun-setting and sunrising, at any particular place, it will be visible there and invisible to the inhabitants of the opposite hemisphere, who have the sun above their horizon at that time; for the sun and moon are in opposite parts of the heavens at the time of a lunar eclipse. And with respect to solar eclipses, it is evident that they can only be seen at any place when the sun is above the horizon of that place. There is, however, a difference with regard to the visibility of a solar and lunar eclipse; for an eclipse of the moon has the same appearance to all the inhabitants of that hemisphere to which the moon is visible at the time, owing, in part, to the small distance of the moon from the earth. But an eclipse of the sun may be visible to some places and invisible to others in the same hemisphere of the earth, because the moon's shadow is small in comparison of the earth; for its breadth, excluding the penumbra, is only about 180 miles even in central eclipses.* Hence those places which are considerably distant from the path of the shadow will either have no eclipse at all, or a very small one; while places near the middle of the shadow will have the greatest possible. There is also a difference in the absolute time at which a solar eclipse happens at the various places where it is visible; for it appears more early to the western parts, and later to the eastern, on account of the motion of the moon (and of course her shadow) from west to east.

In most solar eclipses the moon's disc may be observed by a telescope to be covered by a faint light, which is attributed to the reflexion of light from the illuminated part of the earth. When the eclipses are total, the moon's limb is surrounded by a pale circle of light, which some astronomers consider as an indication of a lunar atmosphere, but others, as occasioned by the atmosphere of the sun; because it has been observed to move equally with the sun and not with the moon.

Dr. Halley, in describing a central eclipse of the sun, which happened at London in April, 1715, says, that although the disc of the sun was wholly covered by the moon, a luminous ring of a faint pearly light surrounded the body of the moon the whole time; and its breadth was nearly a tenth of the moon's diameter.

In lunar eclipses, the moon seldom disappears entirely: and on some occasions, even the spots may be distinguished through the shade; but this can only be the case when the moon is at her greatest distance from the earth at the time of the eclipse, for the nearer the moon is to the earth the darkness is the greater. In some instances, the moon has disappeared entirely; and the celebrated astronomer, Heraclius, has taken notice of one where the moon could not be seen even with a telescope, though the night was remarkably clear.

Although eclipses of the sun and moon were long considered by the ignorant and superstitious as presages of *evil*, yet they are of the greatest use in astronomy, and may be employed to improve some of the most important and useful of the sciences. By eclipses of the moon the *earth* is proved

* If there be seven eclipses in any year, five of them must be of the sun and two of the moon.

* A penumbra is the faint shadow produced by an opaque body when opposed to a luminous one.

to be of a *globular* form, the sun to be *greater* than the *earth*, and the *earth* greater than the *moon*. When they are similar in all their circumstances, and happen at considerable intervals of time, they also serve to ascertain the real period of the moon's motion. In geography, eclipses are of considerable use in determining the longitude of places, and particularly eclipses of the moon, because they are oftener visible than those of the sun, and the same eclipse is of equal magnitude and duration at all places where it is seen. In chronology, both solar and lunar eclipses serve to determine exactly the time of any past event.

For the purpose of finding the longitude at places on the earth, eclipses of Jupiter's satellites are found much more useful than eclipses of the moon; not only on account of their happening more frequently, but on account of their instantaneous commencement and termination.

When Jupiter and any of his satellites are in a line with the sun, and Jupiter between the satellite and the sun, it disappears, being then eclipsed, or involved in his shadow. When the satellite goes behind the body of Jupiter, with respct to a spectator on the earth, it is said to be *occulted*, being hid from our sight by his body, whether in his shadow or not. And when the satellite comes into a position between Jupiter and the sun, it casts a shadow on the face of that planet, which is seen by a spectator on the earth as an obscure round spot. Lastly, when the satellite is in a line with Jupiter and the earth, it appears on his disc as a round black spot, which is termed a transit of the satellite.

As those phenomena appear at the same moment of *absolute* time at all places on the earth to which Jupiter is then visible, but at different hours of *relative* time, according to the distance between the meridian of the places at which observations are made, it follows that this difference of time converted into degrees will be the difference of longitude between those places.* Suppose, for example, that a person at London observed an eclipse to begin at 11 o'clock in the evening, and that a person at Barbadoes observed the same at seven o'clock in the evening, it is certain the eclipse was seen by both persons at the same moment of absolute time, although there is four hours difference in their manner of reckoning that time: and this converted into degrees (at the rate of 15 degrees to an hour) is the difference of longitude between these two places — therefore Barbadoes is 60 degrees *west* from London, the time not being so far advanced there as at London.

Another phenomena, somewhat similar to an eclipse, sometimes takes place, by which the longitude of places may be determined, although not quite so easily, nor perhaps so accurately, as by the eclipses of Jupiter's satellites. This is the hiding or obscuring of a fixed star or planet by the moon or other planet, which takes place when the moon or planet is in conjunction with the star. Appearances of this kind are termed occultations. They are very little attended to except by practical astronomers, who employ them for the correction of the lunar tables, and settling the longitude of places, as already stated.

* *Absolute* time is that which is computed from the same moment; *relative* is that which is computed from different moments.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF HYPATIA.

Hypatia, a most beautiful, virtuous, and learned lady of antiquity, was the daughter of Theon, who governed the Platonic school at Alexandria, the place of her birth and education, in the latter part of the fourth century. Theon was famous among his contemporaries for his extensive knowledge and learning; but what has chiefly rendered him so with posterity is, that he was the father of Hypatia, who, encouraged by her prodigious genius, he educated not only in all the qualifications belonging to her sex, but likewise in the most abstruse sciences. She made an amazing progress in every branch of learning, and the things that are said of her almost surpass belief. Socrates, the ecclesiastical historian, a witness whose veracity cannot be doubted, at least when he speaks in favour of a heathen philosopher, tells us, that Hypatia "arrived at such a pitch of learning, as very far to exceed all the philosophers of her time." Philostorgius, a third historian of the same stamp, affirms, that "she was much superior to her father and master, Theon, in what regards Astronomy;" and Suidas, who mentions two books of her writing, one "On the Astronomical Canon of Diophantus, and another on the Conics of Apollonius," avers, that "she not only exceeded her father in Astronomy, but also that she understood all the other parts of philosophy." It is some confirmation of these assertions, that she succeeded her father in the government of the Alexandrian school: filling that chair, where Ammonius, Hierocles, and many great and celebrated philosophers had taught; and this, at a time, when men of immense learning abounded both at Alexandria, and many other parts of the Roman empire. Her fame was so extensive, and her worth so universally acknowledged, that we cannot wonder if she had a crowded auditory. "She explained to her hearers," says Socrates, "the several sciences that go under the general name of philosophy; for which reason there was a confluence to her, from all parts, of those who made philosophy their delight and study."

Her scholars were as eminent as they were numerous: one of whom was the celebrated Synesius, who was afterwards Bishop of Ptolemais. This ancient Christian Platonist every where bears the strongest, as well as the most grateful testimony to the learning and virtue of his instructress; and never mentions her without the profoundest respect, and sometimes in terms of affection coming little short of adoration. In a letter to his brother Euoptius, "Salute," says he "the most honoured and the most beloved of God, the Philosopher; and that happy society, which enjoys the blessing of her divine voice." In another, he mentions one Egyptus, who "sucked in the seeds of wisdom from Hypatia." In another, he expresses himself thus: "I suppose these letters will be delivered by Peter, which he will receive from that sacred hand." In a letter addressed to herself, he desires her to direct a hydroscope to be made and brought for him, which he there describes. That famous silver astrolabe, which he presented to Peonius, a man equally excelling in philosophy and arms, he owns to have been perfected by the directions of Hypatia. In a long epistle, he acquaints her with his reasons for writing two books, which he sends her; and asks her judgment of one, resolving not to publish it without her approbation.

But it was not Synesius only, and the disciples of the Alexandrian school, who admired Hypatia for her great virtue and learning; never woman was more caressed by the public, and yet never woman had a more unspotted character. She was held as an oracle for her wisdom, which made her consulted by the magistrates in all important cases; and this frequently drew her among the greatest concourse of men, without the least censure of her manners. "On account of the confidence and authority," says Socrates, "which she had acquired by her learning, she sometimes came to the judges with singular modesty. Nor was she any thing abashed to appear thus among a crowd of men; for all persons, by reason of her extraordinary discretion, did at the same time both reverence and admire her." The same is confirmed by Nicephorus and other authors, whom we have already cited. Damascius and Suidas relate, that the governors and magistrates of Alexandria regularly visited her, and paid their court to her; and when Nicephorus intended to pass the highest compliment on the Princess Eudocia, he thought he could not do it better, than by calling her "another Hypatia."

While Hypatia thus reigned the brightest ornament of Alexandria, Orestes was governor of the same place for the emperor Theodosius, and Cyril bishop or patriarch. Orestes, having had a liberal education, admired Hypatia, and frequently consulted her. This created an intimacy between them that was highly displeasing to Cyril, who had a great aversion to Orestes: which intimacy, as it is supposed, had like to have proved fatal to Orestes, as we may collect from the following account of Socrates. "Certain of the monks," says he, "living in the Nitrian mountains, leaving their monasteries to the number of about five hundred, flocked to the city, and spied the governor going abroad in his chariot: whereupon approaching, they called him by the names of Sacrificer and Heathen, using many other scandalous expressions. The governor, suspecting that this was a trick played him by Cyril, cried out that he was a Christian, and that he had been baptised at Constantinople by Bishop Atticus. But the monks giving no heed to what he said, one of them, called Ammonius, threw a stone at Orestes, which struck him on the head; and being all covered with blood from his wounds, his guards, a few excepted, fled, some one way and some another, hiding themselves in the crowd, lest they should be stoned to death. In the mean while, the people of Alexandria ran to defend their governor against the monks, and putting the rest to flight, brought Ammonius, whom they apprehended, to Orestes; who, as the laws prescribed, put him publicly to the torture, and racked him till he expired.

But though Orestes escaped with his life, Hypatia afterwards fell a sacrifice. This lady, as we have observed, was profoundly respected by Orestes, who much frequented and consulted her: "for which reason," says Socrates, "she was not a little traduced among the Christian multitude, as if she obstructed a reconciliation between Cyril and Orestes. This occasioned certain enthusiasts, headed by one Peter, a lecturer, to enter into a conspiracy against her; who, watching an opportunity, when she was returning home from some place, first dragged her out of her chair, then hurried her to the church called Cæsar's, and, stripping her naked, killed her with tiles. After this they tore her to pieces; and carrying her limbs to a place called Cinaron, there burnt them to ashes." Cave endeavours to remove the imputation of this horrid murder from Cyril, thinking him too honest a man to have had any hand in it; and lays it upon the Alexandrian mob in general, whom he calls "a very trifling inconstant people." But though Cyril should be allowed to have been neither the perpetrator, nor even the contriver of it, others have thought that he did not discountenance it in the manner he ought to have done: and was so far from blaming the outrage committed by the Nitrian monks upon the governor Orestes, that "he afterwards received the dead body of Ammonius, whom Orestes had punished with the rack; made a panegyric upon him, in the church where he was laid, in which he extolled his courage and constancy, as one that had contended for the truth; and, changing his name to Thaumasius, or the Admirable, ordered him to be considered as a martyr. However," continues Socrates, "the wiser sort of Christians did not approve the zeal which Cyril showed on this man's behalf, being convinced, that Ammonius had justly suffered for his desperate attempt." We learn from the same historian, that the death of Hypatia happened in March, in the 10th year of Honorius's, and the 6th of Theodosius's, consulship; that is, about A.D. 415.

IMPROVED HYDRAULIC RAM.

Amongst the various mathematical instruments and models of machines which issue from the cabinet of M. A. F. L., and are sold at Paris, in the Rue Castex, there is to be seen an hydraulic ram, constructed by Mr. Smith, under the superintendence and direction of M. Montgolfier, jun., and which we shall here describe. All its parts are extremely simple, but as well adjusted, and as neatly executed, as the most finished philosophical instrument. It is unquestionably the most complete and perfect machine of the kind that has ever been constructed. Its operations are performed with great exactness, its action is regular, and its effects are constant.

It is constructed so as to raise seven pints of water in a minute to the height of 64 feet, at an expense of a stream of water of $2\frac{1}{2}$ inches, and 30 inches fall; the quantity and height may, however, both be augmented by elevating the fall.

Those parts which comprise the tubes of the great pipe of 30 feet in length and 64 in height, are formed of copper, with admirable perfection. The tubes are of red copper, without solder, every foot of which is strengthened by strong brass rods, an indispensible precaution for preserving their stiffness. These tubes are formed in parts of equal length, and each of the length of five feet six inches, and fastened together by means of *braces* in brass work, polished with emery, as the spigot of a cask; and when they are all mutually connected with each other, the whole is consolidated by a covering of the same metal, screwed and locked with a key.

The apparatus is provided in several parts with a number of valves, formed of metal of different alloys, and of porcelain, agate, or leather, &c. &c.; which are employed in making interesting experiments upon their relative duration and advantage, in order that they may be replaced when it is found necessary.

This excellent hydraulic ram may be erected in a few hours, wherever its action is requisite, without allowing a single drop of water to escape. In fact, all the parts which compose it may be taken to pieces with equal facility, and packed into a case of five feet eight inches in length, and only 16 inches in depth; which may also serve to contain any other philosophical instrument.

There is an apparatus for *the admission or reception of air*, which conforms exactly to each stroke of the *ram*; the purpose of which is to keep in a constant level and a permanent density the air which is contained in the bell of the machine, or in the compressing *globe*, which thus supplying the loss of air which is absorbed in its compression by the water, to maintain the elasticity of the surrounding air, so necessary to the operation of machines for raising columns of water, to avert any sudden jerks, prevent their fracture, and to regulate their movements.

The perfection of the hydraulic ram is to be ascribed entirely to M. Montgolfier, jun. In fact, the ram, deprived of this latter improvement, would never move with any regularity; it either bursts, or stops suddenly, the moment the air in the *bell* is absorbed. In this case, if the tubes of ascension are brittle as those of cast iron are, they split into a hundred pieces; if soft like lead, they tear; and, lastly, if they be elastic as copper, the machine affords no further produce; for the tubes dilating and contracting alternately the *pulsations* of the ram, proceed no further than occasioning a movement, or rather an oscillation up and down, entirely useless in the column of ascending water; a capital defect in this species of machinery, and which was not considered by the original inventors, but which the apparatus *for the inspiration of air* occasions to be overcome.

This ram will perform its operations regularly during three months without stopping, if it is not touched or damaged; it is true, that great care must be taken to place it in a proper position, and to shelter or protect it from the weather.

It cannot be too strongly represented to those persons who intend to employ the powers of this hydraulic ram, that the greater part of the defects in this ingenious engine arise not from its construction, but solely from the wretched economy observed in its formation, and, above all, from the negligence and carelessness of the workmen who assist in fitting it up; who seldom possess either the knowledge or the experience necessary to ensure its successful operation.

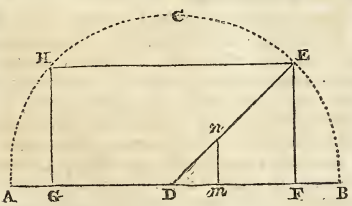
All the parts of the hydraulic ram here described were removed from the foundry, as soon as it was possible, without running the risk of having them too weak, or of endangering their solidity; therefore there is no superfluous metal attached to them. The cost amounted to the sum of three francs per pound, including the cost of workmanship. The whole weight is 90 *kilogr.* (or 180 pounds de *marc*). All its parts were put to the test, and were found to be of sufficient strength. This ram is provided with all the necessary *filtres*, and is complete in all its parts. The cost cannot be estimated at less than five francs per pound; and the whole amount will be about 900 francs, or £36 sterling.

Note.—There is attached to it a description of the method of raising it and putting it in action.

SOLUTION OF QUESTIONS.

QUEST. 43, *answered by* Mr. J. TAYLOR, *Clement's-lane, Lombard-street.*

Let A B C denote the given elipsis,



D its centre, make D m = half n, and make $m\,n = c$; join D n, continuing it till it cuts the arch E, draw E F parallel to $m\,n$, and E H parallel to G F; lastly, draw G H parallel E F, then is H G E F the rectangle required.

DEMON. The triangles D $m\,n$, and D E F are similar, consequently as D m : mn :: D F : E F. Then, as twice D m : mn :: twice D F : EF. Q. E. D.

This problem was also solved by the Proposer, nearly in a similar manner.

QUEST. 44, *answered by* MR. WHITCOMBE, *Mathematician, Cornhill.*

Put $2\,a = £20$, the sum of A and B's share; $m = £602$, the difference of the cubes of their shares, and $x =$ half the difference of their shares, then will $a + x$ = A's share, and $a - x =$ B's share; then per question $\overline{a+x}|^3 - \overline{a-x}|^3 = m$; expanded and reduced, we obtain $2\,x^3 + 6^2\,a\,x = m$, a cubic, which per Cardan we find $x = 1 \therefore a + x = 10 + 1 = £11 =$ A's share, and $a - x = 10 - 1 = £9 =$ B's share as required.

This question was also solved by Mr. J. TAYLOR; by Mr. J. HARDING; by Mr. J. BARR; and we received an answer from a CONSTANT READER, but without any operation. The above is a very neat solution; and though we have no room to insert it, we have received another equally neat from T. D. *Bristol.* ED.

QUEST. 45, *answered* by Mr. J. STEPHENS.

The circumference of a circle, whose radius is 10 feet is 753·984 inches; and as the screw must sink 1 inch in one revolution as 1 : 753·984 :: 200 : 105796·8 pounds, which is the pressure of the screw.

This question was also solved by a CONSTANT READER; by Mr. J. JOHNSTON; and by the Proposer, who have mistaken the radius for the circumference, by which means they have made the answer only half the above.

QUESTIONS FOR SOLUTION.

QUEST. 47, *proposed by* T. D. *Bristol.*

It is required to find the distance (on a horizontal plane) from the base of the tower of Bristol Cathedral, to the image of the sun, in a basin of water, which may be observed by a person from the top of the tower on the 29th of April, 1825, at 11 h. 5 m. 22 s. in the morning; the height of the tower being 127·63 feet, and the observer's eye 5·57 feet above the tower, in lat. 51° 27′ 6″. 3 N., long. 2° 35′ 28″. 6 W.

QUEST. 48, *proposed by* Mr. J. WHITCOMBE, *Cornhill.*

In the equation $2{\cdot}943271\,x - x^3 = 1{\cdot}94353929$, it is required to find the three roots of x by a strict algebraic process, without making use of conjecture, or following the methods of Newton, Ward, Hutton, Emerson, or any of the modern authors on Algebra.

We have inserted the above question at the earnest request of the Proposer; but we wish it to be understood, that abstract mathematical questions are not what we wish. See our standing notice to Correspondents on the Wrapper. ED.

ERRATA.—For Quest. 42, page 320, *read* 41—and for Quest. 43, *read* 42.

GEOMETRY.

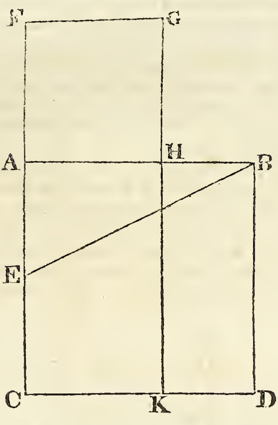
PROPOSITION XI.

Problem.—*To divide a given straight line into two parts, so that the rectangle contained by the whole, and one of the parts, shall be equal to the square of the other part.*

Let A B be the given straight line; it is required to divide it into two parts, so that the rectangle contained by the whole, and one of the parts, shall be equal to the square of the other part.

Upon A B describe the square A B D C; bisect A C in E, and join B E; produce C A to F, and make E F equal to E B, and upon A F describe the square F G H A; A B is divided in H, so that the rectangle A B, B H, is equal to the square of A H.

Produce G H to K: because the straight line A C is bisected in E, and produced to the point F, the rectangle C F, F A, together with the square of A E, is equal to the square of E F: But E F is equal to E B; therefore the rectangle C F, F A, together with the square of A E, is equal to the square of E B: And the squares of



B A, A E are equal to the square of E B, because the angle E A B is a right angle; therefore the rectangle C F, F A, together with the square of A E, is equal to the squares of B A, A E: Take away the square of A E, which is common to both, therefore the remaining rectangle C F, FA, is equal to the square of A B; and the figure F K is the rectangle contained by C F, F A, for A F is equal to F G; and A D is the square of A B; therefore F K is equal to A D: Take away the common part A K, and the remainder F H is equal to the remainder H D: And H D is the rectangle contained by A B, B H, for A B is equal to B D; and F H is the square of A H. Therefore the rectangle A B, B H is equal to the square of A H: Wherefore, the straight line A B is divided in H, so that the rectangle A B, B H, is equal to the square of A H. Which was to be done.

This proposition is one of those which cannot be proved by numbers; and shows that Geometry is a more accurate branch of the mathematics than arithmetic, at least where it is applicable.

The solution by numbers may, however, be approximated to sufficiently near for any purpose that may be required, by solving a quadratic equation in algebra; but as we are aware that comparatively few can perform this operation, we shall here give a very easy mode of approximation.

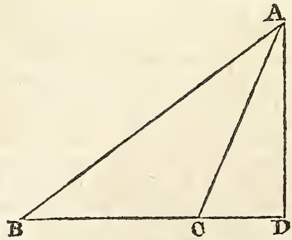
Assume the segments of the divided line at first equal, and denote each by 1, then their continued summation will produce the following numbers: 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, &c. Now if the divided line contained 89 equal parts, its greater segment would contain 55, and its lesser segment 34 of these parts, very nearly; and if the whole line contained 144 parts, its greater segment would contain 89, and its lesser segment 34 of these parts, which is an approximation still nearer than the foregoing.

PROPOSITION XII.

Theorem.—*In obtuse-angled triangles, if a perpendicular be drawn from any of the acute angles to the opposite side produced, the square of the side subtending the obtuse angle is greater than the squares of the sides containing the obtuse angle, by twice the rectangle contained by the side upon which, when produced, the perpendicular falls, and the straight line intercepted without the triangle between the perpendicular and the obtuse angle.*

Let A B C be an obtuse angled triangle, having the obtuse angle A C B, and from the point A let A D be drawn perpendicular to B C produced: The square of AB is greater than the squares of A C, C B, by twice the rectangle B C, C D.

Because the straight line B D is divided into two parts in the point C, the square



of B D is equal to the squares of B C, C D, and twice the rectangle B C, C D: To each of these equals add the square of D A; and the squares of B D, D A, are equal to the squares of B C, C D, D A, and twice the rectangle B C, C D: But the square of B A is equal to the squares of B D, D A, because the angle at D is a right angle; and the square of C A is equal to the squares of C D, D A: Therefore the square of B A is equal to the squares of B C, C A, and twice the rectangle B C, C D; that is, the square of B A is greater than the squares of B C, C A, by twice the rectangle B C, C D. Therefore, in obtuse-angled triangles, &c. Q. E. D.

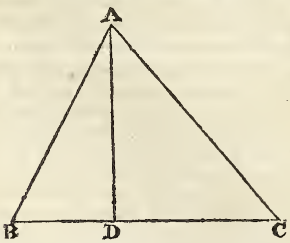
This and the following propositions would be rendered more intricate, by any attempt to illustrate them by numbers.

PROPOSITION XIII.

THEOREM.—*In every triangle, the square of the side subtending any of the acute angles, is less than the squares of the sides containing that angle, by twice the rectangle contained by either of these sides, and the straight line intercepted between the perpendicular let fall upon it from the opposite angle, and the acute angle.*

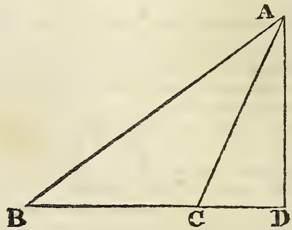
Let A B C be any triangle, and the angle at B one of its acute angles, and upon B C, one of the sides containing it, let fall the perpendicular A D from the opposite angle: the square of A C, opposite to the angle B, is less than the squares of C B, B A, by twice the rectangle C B, B D.

First, let A D fall within the triangle A B C; and because the straight line C B



is divided into two parts in the point D, the squares of C B, B D are equal to twice the rectangle contained by C B, B D, and the square of D C: To each of these equals add the square of A D; therefore the squares of C B, B D, D A, are equal to twice the rectangle C B, B D, and the squares of A D, D C: But the square of A B is equal to the squares of B D, D A, because the angle B D A is a right angle; and the square of A C is equal to the squares of A D, D C: Therefore the squares of C B, B A are equal to the square of A C, and twice the rectangle C B, B D; that is, the square of A C alone is less than the squares of C B, B A, by twice the rectangle C B, BD.

Secondly, Let A D fall without the triangle A B C; and because the straight line B D is divided into two parts in C,



the squares of C B and B D are equal to twice the rectangle contained by C B, B D, and the square of D C: To each of these equals add the square of A D; therefore the squares of C B, B D, D A, are equal to twice the rectangle C B, B D, and the squares of A D, D C: But the square of A B is equal to the squares of B D, D A, because the angle B D A is a right angle; and the square of A C is equal to the squares of A D, D C: Therefore the squares of C B, B A are equal to the square of A C, and twice the rectangle C B, B D; that is, the square of A C alone is less than the squares of C B, B A by twice the rectangle C B, B D.

Lastly, let the side A C be perpendicular to B C; then is B C the straight line between the perpendicular and the acute angle at B; and it is manifest, that the squares of A B, B C are equal to the square of A C and twice the square of B C: Therefore, in every triangle, &c. Q. E. D.

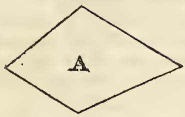
PROPOSITION XIV.

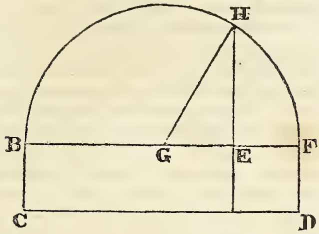
PROBLEM.—*To describe a square that shall be equal to a given rectilineal figure.*

Let A be the given rectilineal figure; it is required to describe a square that shall be equal to A.

Describe the rectangular parallelogram B C D E equal to the rectilineal figure A.

If then the sides of it B E, E D are equal





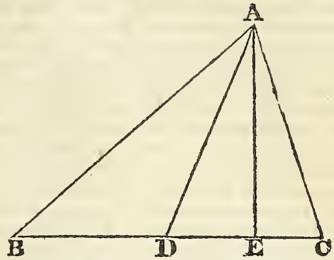
to one another, it is a square, and what was required is now done: But if they are not equal, produce one of them B E to F, and make E F equal to E D, and bisect B F in G: and from the centre G, at the distance G B, or G F, describe the semicircle B H F; and produce D E to H, and join G H: Therefore, because the straight line B F is divided into two equal parts in the point G, and into two unequal at E, the rectangle B E, E F, together with the square of E G, is equal to the square of G F: But G F is equal to G H; therefore the rectangle B E, E F, together with the square of E G, is equal to the square of G H: But the squares of H E E G are equal to the square of G H: Therefore the rectangle B E, E F, together with the square of E G, is equal to the squares of H E, E G: take away the square of E G, which is common to both; and the remaining rectangle B E, E F is equal to the square of E H: but the rectangle contained by B E, E F is the parallelogram B D, because E F is equal to E D; therefore B D is equal to the square of E H; but B D is equal to the rectilineal figure A; therefore the rectilineal figure A is equal to the square of E H: Wherefore a square has been made equal to the given rectilineal figure A; viz. the square described upon E H. Which was to be done.

PROPOSITION A.

Theorem.—*If one side of a triangle be bisected, the sum of the squares of the other two sides is double of the square of half the side bisected, and of the square of the line drawn from the point of bisection to the opposite angle of the triangle.*

Let A B C be a triangle, of which the side B C is bisected in D, and D A drawn to the opposte angle; the squares of B A and A C are together double of the squares of B D and D A.

From the vertex A, draw A E at right angles to B C,



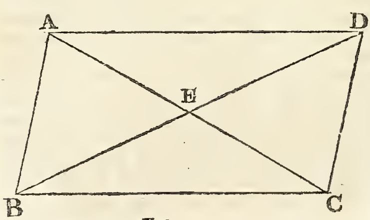
and because B C is divided equally in D, and unequally in E, the squares of B E and E C are together equal to twice the square of B D, and twice the square of D E, (II. 9); to each of these add twice the square of A E, and the squares of B E and E A are equal to the square of A B, and the squares of C E and E A are equal to the square of A C; therefore the squares of A B and A C are equal to twice the square of B D, and twice the squares of D E and A E; but twice the squares of D E and A E are equal to twice the square of A D, therefore the squares of A B and A C are equal to twice the square of B D and of A D.

PROPOSITION B.

Theorem.—*The sum of the squares of the diagonals of any parallelogram, is equal to the sum of the squares of the sides of the parallelogram.*

Let A B C D be a parallelogram, of which the diameters are A C and B D; the sum of the squares of A C and B D is equal to the sum of the squares of A B, B C, C D, D A.

Let A C and B D intersect one another in E: and because the vertical angles A E D, C E B are equal, and also the alternate angles E A D, E C B, the triangles A D E, C E B have two angles in the one equal to two angles in the other, each to each: but the sides A D and B C, which are opposite to equal angles in these triangles, are also equal; therefore the other sides which are opposite to the equal angles are also equal; viz. A E to E C, and E D to E B.



Since, therefore, B D is bisected in E, the squares of A B and A D are equal to twice the square of A E and twice the square of B E; and for the same reason the squares of B C and C D are equal to twice the square of C E and twice the square of D E. Therefore the squares of A B, A D, D C, and C B, are equal to four times the square of B E, and four times the square of A E. But four times the square of B E is equal to the square of B D, and four times the square of A E is equal to the square of A C, because B D and A C are both bisected in E; therefore the squares of A B, A D, D C, and C B, are equal to the squares of A C and B D.

We have added the two last propositions on account of their great Use in Geometry, and their close connection with the propositions which precede them, in the second book. Prop. A. is an extension of the 9th and 10th of the same book; and B is easily proved, after the truth of A is established.

MECHANICS.

ATWOOD'S MACHINE.

(See page 309.)

If $4\frac{3}{4}$ oz. or 19 *m*. be included in either box, this, with the weight of the box itself, will be 25 *m;* so that when the weights A and B, each being 25 *m*, are balanced in the manner represented in the figure, their whole mass will be 50 *m*, which being added to the *inertia* of the wheels 11 *m*, the sum will be 61 *m*. Besides these, three circular weights are constructed, each of which is equal to $\frac{1}{4}$ of an ounce, or 6 *m*. If one of these be added to A and one to B, the whole mass will now become 63 *m*, perfectly in equilibrio, and moveable by the least weight added to either (setting aside the effects of friction) in the same manner precisely, as if the same weight or force were applied to communicate motion to the mass 63 *m*, existing in free space and without gravity.

The moving force. Since the weight of any substance is constant, and the exact quantity of it easily estimated, it will be convenient here to apply a weight to the mass A as a moving force. Thus, when the system consists of a mass equal in weight to 63 *m*, according to the preceding description, the whole being perfectly balanced, let a weight of $\frac{1}{4}$ oz. or *m*, be applied on the mass A; this will communicate motion to the whole system; by adding a quantity of mattter *m* to the former mass 63 *m*, the whole quantity of matter moved will now become 64 *m*, and the moving force being equal to *m*, this will give the force which accelerates the descent of A, equal to $\frac{1}{64}$th part of the accelerating force of gravity.

In this way the moving force may be altered without altering the mass moved; consequently, both the proportion and absolute quantities of the moving force and mass moved may be of any assigned magnitude, according to the conditions of the proposition to be illustrated.

Of the space described. The body A, fig. 1, descends in a vertical line; and a scale E F, about 64 inches in length, divided into inches and tenths, is adjusted vertical, and so placed, that the descending weight A may fall in the middle of a square stage Z, fixed to receive it at the end of the descent; the beginning of the descent is estimated from *o*. The descent of A is terminated when the bottom of the box strikes the stage Z, which may be fixed at different distances from the point *o*; so that by altering the position of the stage, the space described from rest may be of any given magnitude less than 64 inches.

The time of description is observed by the pendulum X W vibrating seconds; and the experiments intended to illustrate the elementary propositions, may easily be so constructed that the time of motion shall be a whole number of seconds. The estimation of the time, therefore, admits of considerable exactness, provided the observer takes care to let the bottom of the box A begin its descent precisely at any beat of the pendulum; then the coincidence of the stroke of the box against the stage, and the beat of the pendulum at the end of the time of motion, will show how nearly the experiment and the theory agree. There might be various devices for letting the weight A begin its descent, at the instant of a beat of the pendulum W; for instance, let the bottom of the box *o*, when *o* on the scale, rest on a flat rod held in the hand horizontally, its extremity being coincident with *o* by attending to the beats of the pendulum, and with a little practice, the rod which supports the box A, may be removed at the moment the pendulum beats, so that the descent of A shall commence at the same instant.

Of the velocity acquired.—It remains only to describe in what manner the velocity acquired by the descending weight A, at any given point of its path, is made evident to the senses. The velocity of A's descent being continually accelerated, will be the same in two points of the space described. This is occasioned by the constant action of the moving force; and, since the velocity of A at any instant is measured by the space, which would be described by it moving uniformly for a given time, with the velocity it had acquired at that instant, this measure cannot be experimentally obtained, except by removing the force by which the descending body's acceleration was caused. But our limits will not permit us to state how this is effected.

In the preceding description, as Mr. Atwood remarks, two suppositions have been assumed, neither of which is mathematically true; but it might be easily shown that they are so in a physical sense, the error occasioned by them being insensible in practice.

The force which communicates motion to the system has been assumed constant; which will be true, only on a supposition, that the line at the extremities of which the weights A and B, fig. 1. are affixed, is without weight.

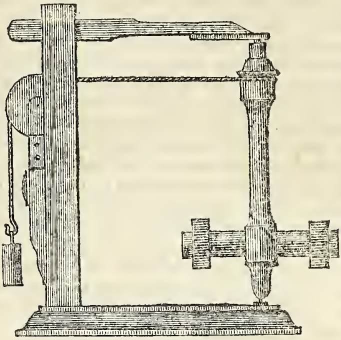
The bodies have also been supposed to move in vacuo, whereas the resistance of the air will have some effect in retarding their motion; but as the greatest velocity communicated in these experiments, cannot much exceed that of about 26 inches in a second; (suppose the limit of 26·2845, and the cylindrical boxes $1\frac{3}{4}$ inches in diameter,) the resistance of the air can never increase the time of descent in so great a proportion, as that of 240 to 241; its effects will therefore be insensible in experiment.

The effects of friction are almost wholly removed by the friction wheels; for when the surfaces are well polished and free from dust, &c. if the weights A and B be balanced in perfect equlibrio, and the whole mass consists of 63 m, according to the example already described, a weight of $1\frac{1}{2}$ grains, or at most 2 grains, being added either to A or B, will communicate motion to the whole, which shows that the effects of friction will not be so great as a weight of $1\frac{1}{2}$ or 2 grains.

In some cases, however, especially in experiments relating to retarded motion, the effects of friction become sensible, but may be very readily and exactly removed, by adding a small weight of 1·5 or 2 grains to the descending body, taking care that the weight added be such, as is in the least degree smaller than that which is just sufficient to put the whole in motion, when A and B are equal, and balance each other before the moving force is applied.

MR. SMEATON'S MACHINE FOR EXPERIMENTS ON ROTATORY MOTION.

The following ingenious apparatus was employed by Mr. Smeaton, in his "Experimental examination of the quantity and proportion of mechanic power, necessary to be employed in giving different degrees of velocity to heavy bodies from a state of rest, with the view of showing that the same mechanic power is capable of producing the same velocity as a given body, whether it is applied, so as to produce it in a greater or less time. The machine is represented by the following figure.



A vertical axis is turned by a thread passing over a pulley, and supporting a scale with weights; the thread may be applied at different parts of the axis, having different diameters, and the axis supports two arms, on which two leaden weights are fixed, at distances which may be varied at pleasure. The same force will then produce, in the same time, but half the velocity, in the same situation of the weights, when the thread is applied to a part of the axis of half the diameter: and if the weights are removed to a double distance from the axis, a quadruple force will be required, in order to produce an equal angular velocity in a given time.*

Now having wound up a certain number of turns of the thread on the barrel, and having placed a weight in the scale, it is obvious that it will cause the axis to turn round and give motion to its arms, and to the weights of lead placed on them, which the heavy bodies to be put in motion by are impulse of the weight in the scale; and when the line is wound off, the scale falls down, and the weight ceases to accelerate the motion of the heavy bodies, and leaves them revolving equally forward with the velocity they have regained; except so far as that velocity must be gradually lessened by the friction of the machine, and the resistance of the air, which being small, the bodies will revolve for some time before their velocity is apparently diminished.

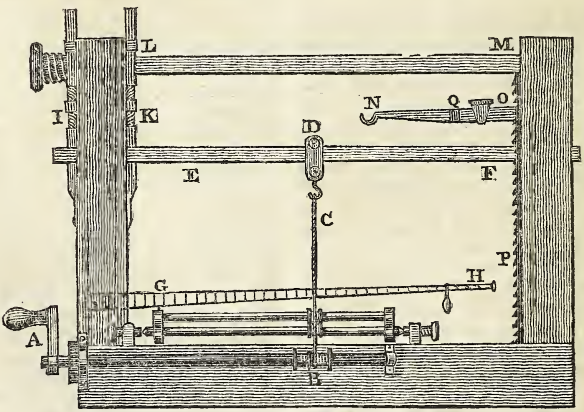
When the bodies are at the smaller distance from the axis of rotation, they are then in effect at half the greater distance

* In a circle, or any portion of a circle, turning round its centre, the square of the distance of this point from the centre, is half the square of the semidiameter; and the whole effect of the momentum of the circle, upon an obstacle at its circumference, is exactly half as great as that of an equal quantity of matter, striking the obstacle with the velocity of the circumference.

from that axis; for, since the axis itself, and the cylindrical arms of wood, keep an invariable distance from the centre of rotation, the bodies themselves must be moved nearer than half their former distance, that, by being compounded with the invariable parts, they may be virtually at the half distance. In order to find this half distance nearly, Mr. Smeaton put in an arm of the same wood, which only passed through the axis, without extending in the opposite direction; one of the bodies being attached to the end of this arm, at the distance of $8\frac{1}{4}$ inches, the whole machine was inclined, till the body and arm became a kind of pendulum, making 92 vibrations in the minute; and as a pendulum of the half length vibrates quicker in the proportion of the square root of 1 to the square root of 2; that is, in the proportion, nearly of 92 to 130; therefore, keeping the same inclination of the machine, the weight was moved on the arm, till it made 130 vibrations in the minute, which was found to be as above stated, when it was at 3·92 inches distant from the centre; which is about $\frac{2}{10}$ths of an inch nearer than the half distance. A double arm was then put in, and marked accordingly; and the bodies being mounted on it, the whole was adjusted ready for use.

MACHINE FOR TRYING THE STRENGTH OF MATERIALS.

In order to investigate the strength of the various substances employed for the purposes of the mechanical arts, it is most convenient to use a machine furnished with proper supports, and gripes, or vices, for holding the materials, and with steel-yards, for ascertaining the magnitude of the force applied, while the extension or compression is produced by a screw or a winch, with the intervention of a wire, a a chain, or a cord: provision ought also to be made for varying the direction of the force, when the flexure of the materials renders such a change necessary. The following figure represents a machiue possessed of these requisites.

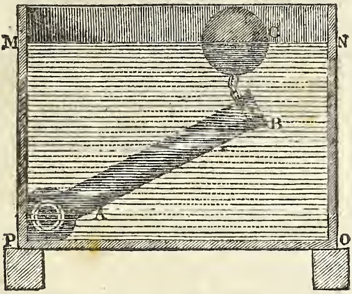


The force is applied by means of the winch A, which winds up the rope B C, passing over the first pulley, and under the second, which is directly under the point D, at which the force acts on the piece E F to be broken; the pulleys slide on two parallel bars, fixed in a frame, which is held down by a point projecting at G, from the lever G H, which is graduated like a steel-yard, and measures the force. The piece to be broken is held by a double vice I K, with four screws, two of them hiding the other two in the figure: if a wire is to be torn, it may be fixed to the cross bar L M; and a substance to be crushed must be placed under the lever N O, the end N receiving the rope, and the end O being held down by the click, which acts on the double ratchet O P. The lever is double from O to Q, and acts on the substance by a loop, fixed to it by a pin.

HYDROSTATICS.

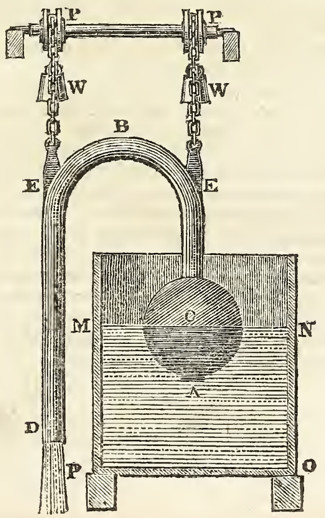
MACHINES FOR DISCHARGING A UNIFORM QUANTITY OF WATER.

The discharge of a uniform quantity of water from a vessel containing it, being a matter of some importance, we shall give a representation of several ingenious contrivances for this purpose. One of these is exhibited by the following figure,



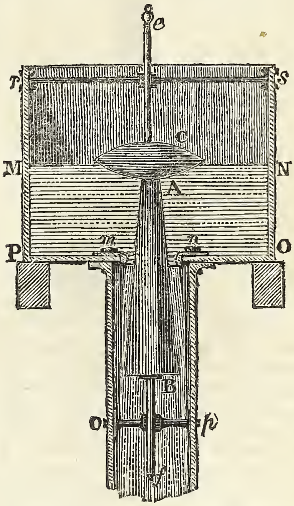
where MNOP is a vessel nearly full of water, which consists of a tube B A moving round a joint at B, and having its upper end B connected with a hollow floating ball C. The velocity with which the water enters the extremity B, is that which is due to the height B C, or the depth B below the surface. As the surface M N descends, the float C also descends, so that whatever be the height of the water in the vessel, it will always enter B with the same velocity. The discharge at the other end A will not be quite uniform, as the water will acquire greater velocity in descending the tube BA when it is much inclined, than when it is nearly horizontal.

A *floating syphon* produces the sam eeffect, but in a more correct manner. This instrument is represented by the following figure,



where A B D is a syphon, with a hollow floating ball at its shorter end. This syphon is suspended by the chains EP, EP, which pass over two pulleys P P upon a horizontal axle P P, and suspend at their other extremities counterweights W W. As the water in the vessel M N O P sinks by being discharged at D, the syphon descends, and the counterweights rise, and an uniform stream is obtained, till the end A reaches the bottom of the vessel.

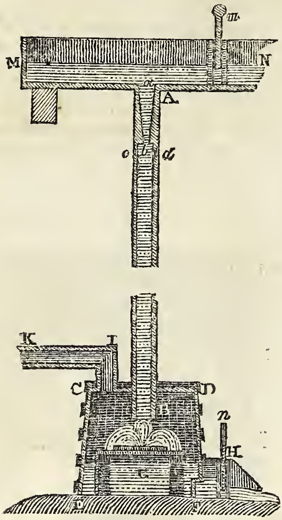
Another very ingenious contrivance for the same purpose, is shown in the following figure.



A cone A B, attached to a lenticular float at C, and fixed upon the axis *e f*, rises and falls in the aperture *m n*, by which the water of the vessel M N O P is to be discharged. It is kept in an upright position by the horizontal axis *o p*, *r s*. Now, when the vessel is full of water, and the head therefore great, the velocity at *m n* will also be great; but as the float C rises with the surface M N, the aperture *mn* will be partly filled by a thicker part of the cone A B; whereas, when the surface M N has descended, the float A B will also descend, and the aperture at *m n* will be widened, in consequence of a smaller part of the cone being included in it. In this way, the varying diameter of the cone always adjusts the aperture *m n* to the variable head of water, so that the quantity discharged through the tube *m n o p*, is nearly always the same.

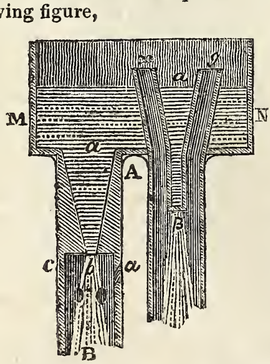
WATER-BLOWING MACHINE, OR SHOWER BELLOWS.

The water-blowing machine, called *trombe* by the French, seems to have been first introduced in Italy about the year 1672, for the purpose of procuring a blast of air by the descent of water. It is represented by the following figure,



where M N is a reservoir of water, in the bottom of which is inserted a long tube A B, consisting of a conical part *a b*, seen upon an enlarged scale in the next fig. communicating with a cylindrical tube *d* B, which enters the vessel C D E F. A number of openings *c*, *d*, &c. are made at the top of the tube *d* B, so that when the water is discharged at the conical aperture *b*, it drags along with it the adjacent air. This mixture of air and water falls upon a stone pedestal G, so as to separate the air from the water.

The water descends to the bottom of the vessel, while the air escapes through the pipe C I K to supply the furnace. Another form of the machine is represented by the following figure,



where $\alpha\beta$ is the conical pipe, and the water is supplied with air from the pipe $\kappa\beta\delta\beta$.

In the water blowing machines used in Dauphiny, in the neighbourhood of the town of Alvar, the diameter of *ab* is 12 inches at *a* and 5 at *b*, the diameter of *d* B is 10 inches. Only four holes are used at *c*, *d*, and the end B enters $1\frac{1}{2}$ feet into the vessel C D E F, which is 4 feet high and 4 feet broad. The water is discharged at an aperture above F a foot in diameter, and sometimes the admission of the water and its discharge are regulated by sluices *m* and *n*. A strong, equal, and continued blast is obtained by this machine, but it is thought to be too moist and too cold. There is one of these machines in Switzerland, which works with great effect at the lead works of M. Lenay, in the valley of Servoz, near Chamouni.

Kircher appears to have been the first who explained the production of wind by a fall of water. Barthes long afterwards gave another theory, and Dietrich and Fabri ascribed the wind to the decomposition of the water. In 1791, the Academy of Thoulouse invited philosophers to investigate this phenomenon, and it was probably in consequence of this that Venturi directed his attention to the subject. This ingenious philosopher has proved that the air is dragged down upon the principle of the lateral communication of motion in fluids; and he has pointed out the best mode of constructing the machine, so as to produce the greatest quantity of air. The diameter of the tube *d* B should be at least double of the aperture *b*. To a height about $1\frac{1}{2}$ feet above C D, the tube should be completely air tight, as well as the vessel C D E F; but above that part the tube *d* B may be perforated in every part with holes.

If the pipe C I K does not discharge all the air which is generated, the surface of the water in the vessel will descend, and part of the air will issue out of the lower apertures of the tube *d* B.

Phenomena similar to those produced by the water-blowing machine, have been observed in nature, at the foot of the cascades which fall from the glacier of Roche Melon, on the naked rock of La Novalese, towards Mount Cenis. Venturi found that the force of the wind arising from the air dragged down by the water could scarcely be withstood. The *ventaroli*, or natural blasts, which are most frequently found to issue from volcanic mountains, arise from the air carried down the hollows by the falls of water; and what are called the *rain winds* have the same origin.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF LEONARD EULER.

Leonard Euler, a very eminent mathematician, was born at Basil, on the 14th of April, 1707, he was the son of Paul Euler and of Margarat Brucker, (of a family illustrious in literature,) and spent the first years of his life at the village of Richen, of which place his father was Protestant minister. Being intended for the church, his father, who had himself studied under James Bernouilli, taught him mathematics, as a ground-work of his other studies, or at least a noble and useful secondary occupation. But Euler, assisted, and perhaps secretly encouraged, by John Bernouilli, who easily discovered that he would be the greatest scholar he should ever educate, soon induced him to declare his intention of devoting his life to that pursuit. This intention the wise father did not thwart; but the son did not so blindly adhere to it, as not to connect with it a more than common improvement in every other kind of useful learning, insomuch, that in his latter days men often wondered how, with such a superiority in one branch, he could have been so near to eminence in all the rest. Upon the foundation of the academy of sciences at St. Petersburgh, in 1723, by Catherine I., the two young Bernouillis, Nicholas and Daniel, had gone thither, promising, when they set out, to endeavour to procure Euler a place in it. They accordingly wrote to him soon after, to apply his mathematics to physiology, which he did, and studied under the best naturalists at Basil, but at the same time; *i. e.* in 1727, published a dissertation on the nature and propagation of sound; and an answer to the question on the masting of ships, which the Academy of Sciences at Paris judged worthy of the *accessit*. Soon after this, he was called to St. Petersburgh, and declared adjutant to the mathematical class in the academy, a class in which, from the circumstances of the times, (Newton, Leibnitz, and so many other eminent scholars being just dead,) no easy laurels were to be gathered. But notwithstanding the great number of mathematicians that flourished about this time, Euler soon took his place among the number. He, indeed, was much wanted; the science of the *Integral Calculus*, hardly come out of the hands of its creators, was still too near the stage of its infancy not to want to be made more perfect. Mechanics, dynamics, and especially hydrodynamics, and the science of the motion of the heavenly bodies, felt the imperfection. Engineering and Navigation were only vague principles, and founded on a number of isolated facts and contradictory observations. The irregularities in the motions of the celestial bodies, and especially the composition of forces which influence the motion of the moon, were still the disgrace of geometers. Practical astronomy had yet to wrestle with the imperfection of the telescope, insomuch, that it could hardly be said that any rule for making them existed. Euler turned his thoughts to all these objects; he perfected the *Integral Calculus;* he was the inventor of a new kind of calculus, that of the arithmetic of *sines;* he simplified analytical operations; and, aided by these powerful helps, and the astonishing facility with which he knew how to subdue expressions the most intractable, he threw a new light on all the branches of the mathematics. But at Catherine's death the academy was threatened with extinction, *by men who knew not the connection which arts and sciences have with the happiness of a people* Euler was offered and accepted a lieutenancy on board one of the Empress's ships, with the promise of speedy advancement. Luckily things changed, and the learned captain again found his own element, and was named Professor of Natural Philosophy in 1733, in the room of his friend, John Bernouilli. The number of memoirs which Euler produced is astonishing; but what he did in 1735 is almost incredible. An important calculation was to be made, without loss of time; the other Academicians had demanded some months to do it. Euler asked only three days—and in that time he did it; but the fatigue threw him into a fever, in which he lost an eye, an admonition which would have made an ordinary man more sparing of the other. The great revolution produced by the discovery of fluxions, had entirely changed the face of mechanics; still, however, there was no complete work on the science of motion, two or three only excepted, of which Euler felt the insufficiency. He saw with pain, that the best works on the subject; viz. "Newton's Principia," and "Herman's Phoronomia," concealed the method by which these great men had come at so many wonderful discoveries, under a synthetic veil. In order to remove this veil, Euler employed all the resources of that analysis, which had served him so well on so many other occasions; and thus uniting his own discoveries with those of other geometers, had them published by the Academy in 1736. To say that clearness, precision, and order, are the characters of this work, would be barely to say that it is, what without these qualities no work can be, classical of its kind. It placed Euler in the rank of the first geometricians then existing, and this at a time when John Bernoulli was still living. Such labours demanded some relaxation; the only one which Euler admitted was music, but even to this he could not go without the spirit of geometry with him. They produced together the essay on a new theory of music, which was published in 1739, but not very well received, probably, because it contains too much geometry for a musician. In 1740, his genius was again called forth by the Academy of Paris, to discuss the nature of the tides. This prize Euler did not gain alone; but he divided it with Maclaurin and D. Bernouilli, forming with them a triumvirate of candidates, which the realms of science had not often beheld. The agreement of the several memoirs of Euler and Bernouilli, on this occasion, is very remarkable. Though the one philosopher had set out on the principle of admitting vortices, which the other rejected, they not only arrived at the same end of the journey, but met several times on the road; for instance, in the determination of the tides under the frozen zone. Philosophy, indeed, led these two great men by different paths; Bernouilli, who had more patience than his friend, established every physical hypothesis he was obliged to make, by painful and laborious experiment. These Euler's impetuous genius scorned; and, though his natural sagacity did not always supply the loss, he made amends by his superiority in analysis. In 1741, Euler received some very advantageous propositions from Frederic the Second, to go and assist him in forming an academy of sciences, out of the wrecks of the Royal Society founded by Leibnitz. With these offers the tottering state of the St. Petersburgh academy under the regency, made it necessary for the philosopher to comply. In 1744, Euler published a complete treatise of isoperimetrical curves; the theory of the motions of the Planets and Comets; the well known theory of magnetism which gained the Paris prize; and the much improved translation of Robins's "Treatise on Gunnery." Navigation was now the only branch of useful knowledge, for which the labours of analysis and geometry had done nothing. The hydrographical part alone, and that which relates to the direction of the course of ships, had been treated by geometricians conjointly with nautical astronomy. Euler was the first who conceived and executed the project of making this a complete science. A memoir on the motion of floating bodies communicated to the academy of St. Petersburgh, in 1735, by M. le Croix, first gave him this idea. His researches on the ebuilibrium of ships, furnished him with the means of bringing the stability to a determined measure. His success encouraged him to go on, and produced the great work which the academy published in 1749, in which we find, in systematic order, the most sublime notions on the theory of the equilibrium and motion of floating bodies, and on the resistance of fluids. This was followed by a second part, which left nothing to be desired on the subject, except the turning it into a language easy of access, and divesting it of the calculations which prevented its being of general use. Accordingly, in 1773, from a conversation with Admiral Knowles, and other assistance, out of the "Scientia Navalis," 2 vols. 4to. was produced, the "Complete Theory of the Construction and Management of Ships." This work was instantly translated into all languages, and the author received a present of 6000 livres from the French king; previous to which he received 300 pounds from the British Parliament, for the *Theorems*, by which Meyer computed his lunar tables.*

Few men of letters have written so much as Euler; no Geometrician has ever embraced so many objects at one time, or has equalled him, either in the variety or magnitude of his discoveries. When we reflect on the good such men do to their fellow-creatures, we cannot help indulging a wish (vain, alas! as it is) for their illustrious course to be prolonged beyond the term allotted to mankind. Euler's, though it has had an end, was very long and very honourable; and it affords us some consolation for his loss, to think that he enjoyed it exempt from the ordinary consequences of extraordinary application, and that his last labours abounded in proofs of that vigour of understanding which marked his early days, and which he preserved to his end. On the 7th of September he talked with Mr. Lexell, who had come to dine with him, of the new planet, and discoursed with him upon other subjects, with his usual penetration. He was playing with one of his grand-children at tea time, when he was seized with an apo-

* It was with great difficulty that this extraordinary man, in 1766, obtained permission from the King of Prussia to return to Petersburgh, where he wished to pass the remainder of his days. Soon after his return, which was graciously rewarded by the munificence of Catherine II. he was seized with a violent disorder, which ended in the total loss of his sight. It was in this distressing situation that he dictated to his servant, a taylor's apprentice, who was absolutely devoid of mathematical knowledge, his Elements of Algebra; which, by its intrinsic merit in point of perspicuity and method, has excited wonder and applause. This work, though purely elementary, plainly discovers proofs of an inventive genius; and it is perhaps here alone that we meet with a complete theory of the analysis of Diophantus.

plectic fit. "I am dying," said he, and he ended his glorious life a few hours after, aged seventy-six years. Euler possessed to a great degree what is commonly called erudition; he had read all the Latin classics; was perfect master of ancient mathematical literature; and had the history of all ages and all nations, even to the minutest facts, ever present to his mind. Besides this, he knew much more of physic, botany, and chemistry, than could be expected from any man who had not made these sciences his peculiar occupation.

Euler was twice married, and had thirteen children, four of whom only survived him. The eldest son was for some time his father's assistant and successor; the second, physician to the Empress; and the third, a lieutenant-colonel of artillery, and director of the armory at Sesterbeck. The daughter married Major Bell. From these children he had thirty-eight grand children. "Never have I been present at a more touching sight than that exhibited by this venerable old man, surrounded, like a patriarch, by his numerous offspring, all attentive to make his old age agreeable, and enliven the remainder of his days by every species of kind solicitude and care."

The catalogue of his works in the printed edition makes 50 pages, 14 of which contain the MS. works. The printed books consist of works published separately, and others to be found in the Petersburgh and Paris Acts, the Berlin Memoirs, and the Transactions of several learned Societies.

OF GUNTER'S SCALE.

As this instrument is much employed in constructing and solving mathematical problems, and as we have frequent occasion to mention the names of the lines marked on that scale, we shall give a short description of its construction, and the various lines marked upon it.

The various lines on this instrument were first laid down on a scale by Mr. Edmund Gunter. The ruler to which these lines are applied is commonly two feet in length, and about an inch and a half or two inches broad, both faces of it being graduated. The lines on the one face are employed for the construction and measurement of figures, both plane and spherical; and those on the other, for resolving, with the help of a pair of compasses, the various problems in trigonometry, and some of the more common operations of arithmetic. To distinguish the lines on the two faces from each other, we shall call the former *natural* lines, and the latter, *logarithmic*, or *artificial*.

The natural lines are the following:

	Marked.
Lines of equal parts - -	
Chords - - - - -	CHO
Rhumbs - - - - -	RHU.
Sines - - - - -	SIN.
Secants - - - - -	SEC.
Tangents - - -	TAN.
Semi-tangents - - -	S. T.
Longitude - - -	M.L.

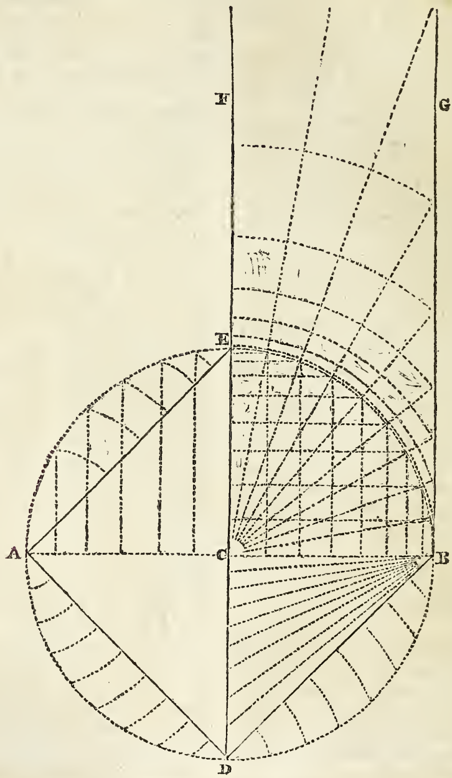
1. *Lines of equal parts.*—The scales to which lines of equal parts are applied are of two kinds, and are denominated *simple* and *diagonal*.

The *Simple Scale* is formed by drawing two parallel lines, and then dividing them at right angles into such a number of equal parts as the destined use of the scale may require. An additional division on the left hand is retained, to be afterwards subdivided into 10 equal parts, for the conveniency of obtaining intermediate lengths between the primary divisions. This scale can only be used for laying off a line, the dimension of which is expressed by two digits, unless 10 of the primary divisions be employed to represent an unit of the next highest order.

The *Diagonal Scale* is constructed by drawing 11 equidistant parallel lines, and then dividing the upper line into as many equal parts as may be thought proper. Through each of the points of division lines are then drawn, cutting the parallel lines at right angles; and the first division, both above and below, is subdivided as before, into 10 equal parts, as represented by the following figure.

In this manner the primary and secondary divisions of the scale are obtained. The ternary or third order of divisions, which must be a tenth of the scondary, are procured by drawing diagonal lines from the 9th of the secondary divisions above, to the 10th of the same division below; from the 8th above to the 9th below, and so on in the case of each corresponding pair of the secondary divisions. By halving each of the primary divisions, and dividing the last one at the other extremity of the scales by diagonal lines, drawn in the same manner, another scale is obtained of half the dimensions. With either of these scales, a line, whose dimension is expressed by three digits, may be laid down or measured with the utmost precision. Thus, let it be required to take from one of these scales, a line, whose length is expressed by 867; place one foot of the compasses in the intersection of the sixth secondary division and the seventh ternary one, and then extend the other foot to the eighth primary division. The extent will correspond to 867. The same extent would also answer to 86·7, 8·67, ·867, &c. or to 8670, 86700, &c. according to the local value assigned to the leading digit; but whatever value is attached to the primary divisions in the measurement of any part of a figure, the same value must be supposed to belong to them in measuring all the other parts.

2. *Line of Chords.*—The line of chords, and the other circular lines on the same side of the scale, have a reference to one another, and are all adapted to the same radius, which is commonly two inches. Let C A



represent that radius, and a circle beng described with it about the centre C, draw the diameters A B and D E at right angles to each other. Divide one of the quadrants as D A into 9 equal parts, and having joined D A, transfer the chords of the several arcs reckoned from A, to the straight line D A, and D A will be a line of chords, exhibiting every 10th division of the scale. The intermediate divisions are obtained by subdividing each of the principal divisions of the quadrant into 10 equal parts, and transferring their chords as before. The scale of chords is employed for laying down or measuring angles, the chord of 60°, which is equal to the radius, being always assumed as the radius of the measuring arc.

3. *Line of Rhumbs.*—The line of rhumbs, which is employed to lay down a ship's course when it is expressed in points, is described in the same manner as the scale of chords, only the quadrant is divided into 8 equal parts in place of 9. Each of the principal divisions is again subdivided into 4 equal parts, and the chords of the resulting arcs being transferred to the straight line B D, the scale of rhumbs is completed.

4. *Line of Sines.*—The line of sines is constructed by dividing one of the quadrants, as B E, into 90 equal parts, as was

done for the scale of chords. Perpendiculars to the radius C E from every division in the quadrant give the line of sines reckoned from C towards E. This line is chiefly used in the orthographic projection of the sphere.

5. *Line of Secants.*—Produce C E indefinitely to F, and through B draw B G parallel to C F and also of unlimited length. Through the centre C, and each division of the quadrant B E, draw straight lines intersecting B G in the divisions 10, 20, 30, &c. The distance of each of these divisions from C being transferred to the line C F, will form the line of secants, which comprehends in it the line of sines, the secant of 0 being equal to the radius, or sine of 90°.

6. *Line of Tangents*—The construction by which the line of secants is obtained, gives at the same time the line of tangents, along the line B G. This line, and the line of secants, are chiefly employed in the stereographic projection of the sphere.

7. *Line of Semitangents.*—The semitangents of arcs are not, as the designation of these lines would imply, the halves of the tangents, but the tangents of half the corresponding arcs Thus the semitangent of 40° is not half the tangent of the 40°, but the tangent of 20°. Hence the scale of semitangents may easily be obtained from the scale of tangents. It may also be obtained by joining the point B, and each of the divisions in the quadrant A D; the intersections of the lines, thus drawn, with the line C D, will give along that line from C, the scale of semitangents. This line, as well as the two preceding, is used in the stereographic projection of the sphere.

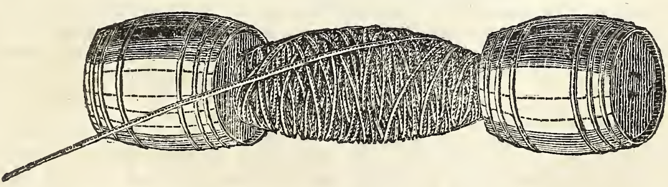
8. *Line of Longitudes.*—To construct the line of longitudes, divide the radius A C into 60 equal parts, and through each of the divisions draw straight lines parallel to C E, and intersecting the quadrantal arc A E. The chords of the resulting arcs, reckoned from A, being transferred to the line A E, will give the line of longitudes. This line being applied, in an inverted order, to a corresponding line of chords 60 in the line of longitude being against 0° on the line of chords, and 0 on the former line against 90° on the latter, if the divisions on the line of chords be considered a line of latitude, the opposite divisions on the line of longitude will exhibit the corresponding number of miles belonging to a degree of longitude, in each particular latitude. This compound line is used to show the convergency of the terrestrial meridians, and to perform instrumentally questions in parallel sailing.

To the Editor of the Artisan.

Sir,

As you have obliged me by publishing a brief description of what I consider the best plan yet invented, for getting a communication with a stranded vessel *from the shore*, I trust you will permit me to describe a simple plan lately invented, and tried with success by a naval officer, for the purpose of gaining the desired communication *from the wreck.** This invention is a buoy of the following description: Let two small casks be connected by a spar going through one head of each, having its ends secured to the inner centers of the other heads, leaving a distance between the casks of rather more than the length of one of them. The spar will then represent an axle, and the casks, two wheels firmly fixed to it, and made water tight. Upon this axle a line is to be reeled in the manner of a log-line, and when thrown overboard, with one end of the line fast to the ship, the power of the wind and sea will keep the casks in continual revolution until the buoy reaches the shore; and it will be found, that, as the line unreels only as the casks revolve, there will be little danger of the bight getting far into the under draught: this might be entirely prevented by making the line buoyant†.

The Buoy, with the Line reeled.



A buoy of this description might be constantly kept slung over the stern or quarter of any vessel at sea, ready for cutting away at a moment's warning, either for the purpose of saving the crew from a wreck, or as a life buoy, in case of a man falling overboard. And in the event of a ship being stranded on a bar or bank at a distance from land, where boats cannot

* Rockets have been recommended to be supplied to ships, for the purpose of carrying a line on shore; and I have no doubt they would in many cases have the desired effect.

† In the 32d vol. Trans. Soc. Arts, may be seen an account of Mr. Cleghorn's invention of a buoyant line; and a life buoy or boat invented by Mr. T. Boyce.

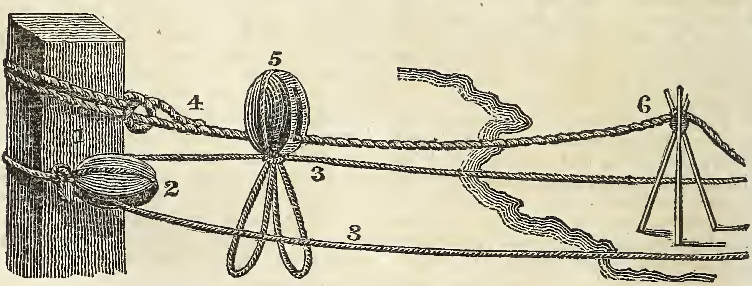
get alongside the wreck, this buoy being cut away, would carry a line from the ship to a boat, by which means a communication would be formed, which might ensure the safety of the crew.

The necessity of adopting some General Plan, after a communication is established between the shore and stranded vessel, which should be understood, not only by all persons having charge of mortars, but also by the crews of all coasting and other vessels, is so apparent, that I trust you will still farther oblige me, by making public the following as an outline, to be improved upon as circumstances may require.

The line thrown from the mortar should not be less than 2-inch, which an 8-inch mortar, within its chamber bored to contain 20 ounces of powder, would throw from 250 to 300 yards; immediately this is received on board, the crew should reeve the end through a tail-block, and haul off as much as will be sufficient for the end and bight to go on shore again, in which they may be guided by a seizing, or stop seized on by the people on shore for that purpose; when this stop reaches the block, the end is to be secured to it, and both parts being hauled on shore, a single whip purchase will be formed, by which the people on shore may haul off, whatever the situation of the wreck may render most advisable for bringing the crew on shore.*

If time and the circumstances of the case will admit, the end of a 3 and ½ or 4-inch hawser should now be hauled off, which the crew must secure just above the tail-block, and which should be either at the mast-head, bowsprit-end, or most elevated part of the Hull, as the master may deem most advisable, in which he will be guided by the state of the mast, bowsprit, &c. always remembering that the higher it can be placed, under the lower mast heads with safety, the better. This hawser is to be rove through a single block, strapped with two grommets under it, just long enough for a man to sit in each, holding on below the block. When the end of the hawser is fast on board, this block is to be hauled off by one part of the whip, and two men may get into the grommets, and be hauled on shore by the other part. The block, &c. being thus hauled to and fro, as often as it may be necessary to bring the whole crew on shore. At all stations having a flat beach, a strong triangle should accompany the apparatus, for the purpose of raising the hawser on shore, with a snatch-block for it to traverse in; when a party of men must keep the hawser in hand, so as to ease it occasionally to the motion of the vessel, and to keep the crew as much out of the water as possible in their passage from the wreck.

The whole apparatus is represented by the following figure:—



1. Represents the mast head, or any other part to which the hawser, &c. is secured—2, the tail-block, through which the whip or hauling line is rove—3, 3, the two parts of the whip—4, the hawser—5, the block and grommets, or traveller—6, the triangle, with snatch-block on the beach.

Permit me in conclusion to observe, that this plan is not merely theoretical, it having been invented in 1800, and since put in practice with success, under some of the most trying circumstances of shipwreck. I am, Sir,

Your obedient humble servant,

NAVARCHUS.

* Various machines have been invented for the purpose of bringing the people on shore from stranded vessels. To particularize, or fully describe any of these very praiseworthy inventions at present would be trespassing too much on your valuable miscellany; but it may be right here to observe, that whenever men are obliged to swim for their lives, or be drawn through the water, they should always endeavour *to face the sea*, that by so doing they may be prepared to hold their breath, and allow the heaviest to pass over them. And let them bear in mind, that in the most apparently desperate situations.

"The brave man ne'er despairs—
And lives where cowards die!"

To the Editor of the Artisan.

SIR,

As aerostation, or the practice of sailing through air, has of late become a thing of common occurrence in this country; and perhaps, the art has arrived at a *greater state* of *perfection*, than at any other *period*, whether it will continue to afford only a speculative amusement, or arrive at any state of practical utility, time and the developement of science can only determine.

As aeronauts are not *always* scientific men and equal to the task they undertake, it becomes the duty of philosophical minds to suggest such improvements as shall, from time to time, occur to them; however, in making the following suggestions, it is but justice to myself to state, that I know nothing of aerostation; having never seen a balloon otherwise than at a considerable elevation.

Mr. Graham, in his account of a late ascension, tells us, "that owing to the density of the atmosphere, he was *compelled* to discharge the *whole* of his ballast, and on arriving into *lighter air*, he ascended with astonishing rapidity to the height of 2½ miles!" To return to a more rational distance, from the earth: the only means in the power of the aeronaut is, by a discharge of the gas; I am of opinion that the gas and also the ballast, would be much better (if possible) retained till the balloon has nearly reached the earth.

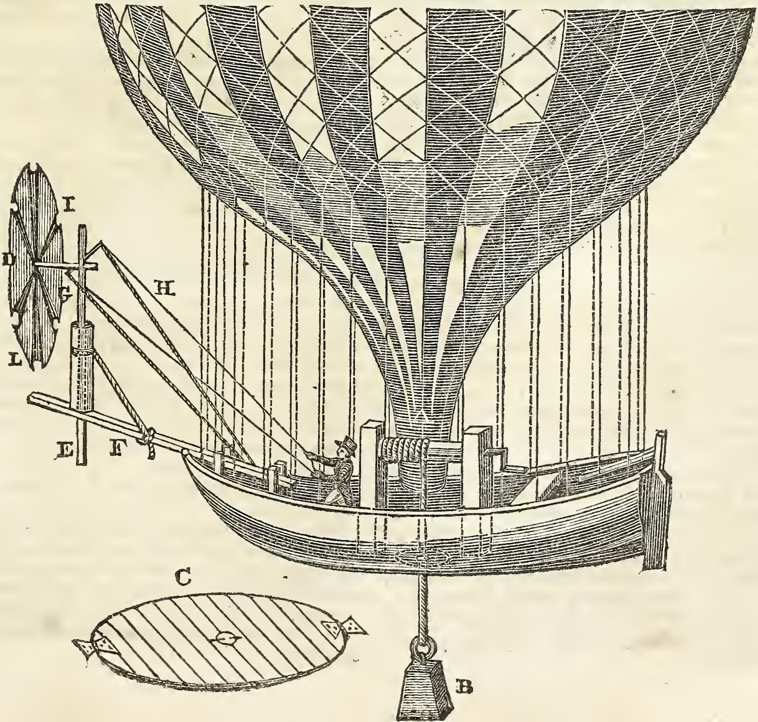
Suppose a weight of several pounds, to be suspended from a machine, through a hole in the centre of the car, to be wound up, or let down, at leisure; would not such suspension have the two-fold effect, of retarding its progress, and, by adding to its specific gravity, cause it to descend? If so, it follows of course, that by winding up the said weight, you accelerate its motion and consequently ascend.

I think it will be evident to every one, that the balloon with its appendages cannot possibly move so rapidly with a pendulum suspended, at a considerable distance, as if no such pendulum was attached. And also that its elongation or contraction, must add to, or diminish its specific gravity.*

If the balloon be sufficiently inflated, to allow its ascension, with a considerable portion of cord suspended; there would be no necessity for so early a discharge of ballast, which would be thus reserved for the regulation of the decent, in my humble opinion, a great desideratum: as all aerial voyagers are agreed, that the descent is the most dangerous part of the voyage.

To prevent a rotatory motion, I have constructed a wheel or vertical fly on the end of the car, which, I presume, if properly managed, would have the desired effect. This apparatus is represented by the following figure.

* We cannot see how the balloon can either ascend or descend by raising or lowering a weight any distance, to which a balloon can ascend. ED.



Here A is the machine, B the weight above alluded to, and C a section of the car.

F is a bowsprit fixed horizontally to the end of the car; on a spindle* affixed to the perpendicular E, revolves (vertically) the fly D; should the balloon have a tendency to veer round to the eastward, the fly would be acted upon at I, but the impulse would be resisted at L. The equilibrium of the fly being thus maintained, it will continually revolve with a velocity in proportion to the *rate* at which the balloon passes through the air.

Knowing the estimation in which your valuable pages are held by the lovers of science *generally*, I shall not attempt to fill them by answering the many objections that may possibly be urged against the proposed fly, leaving it for the adoption, improvement, or rejection, of those more competent to the task than,

Sir,

Your most humble servant,

JOHN TAYLOR.

Clement's Lane, Lombard Street.

* The spindle should be *somewhat* inclined to the horizon, that the fly, by its position and tendency to *fall* upon the wind, may thereby ensure its action.

ELECTROMAGNETIC AND GALVANIC EXPERIMENTS. BY DR. HARE.

If a jet of mercury, in communication with one pole of a very large calorimotor, is made to fall on the poles of a very large horse-shoe magnet communicating with the other, the metallic stream will be curved outwards or inwards, according as one or the other side of the magnet may be exposed to the jet, or as the pole communicating with the mercury may be positive or negative. When the jet of mercury is made to fall just within the interstice formed by a series of horse-shoe magnets, mounted in the usual way, the stream will be bent in the direction of the interstice, and inwards or outwards, according as the sides of the magnet, or the communication with the galvanic poles, may be exchanged. The result is analogous to those obtained by Messrs. Barlow and Marsh with wires, or wheels.

It is well kwown that a galvanic pair, which will, on immersion in an acid, intensely ignite a wire connecting the zinc and copper surfaces, will cease to do so after the acid has acted on the pair for some moments, and that ignition cannot be reproduced by the same apparatus, without a temporary removal from the exciting fluid.

I have ascertained that this recovery of the igniting power does not take place, if, during the removal from the acid, the galvanic surfaces be surrounded either by hydrogen gas, nitric oxide gas, or carbonic acid gas. When surrounded by chlorine, or by oxygen gas, the surfaces regain their igniting power in nearly the same time as when exposed to the air.

The magnetic needle is nevertheless much more powerfully affected by the galvanic circuit, when the plates have been allowed repose, whether it take place in the air, or in any of the other gases above mentioned. *(American Journal of Science.)*

SOLUTIONS OF QUESTIONS.

QUEST. 46, *answered by* A. PEACOCK, St. George's, East.

Let D denote the Debt, F the Fund, R the Ratio, and T the required Time: then the rule for finding T will be $\dfrac{\frac{D}{R} - D + F}{F} = R^T$; therefore, $\frac{600,000,000}{1,035} = 621000000 - 600000000 + 4000000 = 25000000$, which divided by 4·000000, gives 6·25 = ratio involved to a power denoted by the time; now, as the successive divisions to obtain this power by common arithmetic is very prolix, it will be more convenient to employ logarithms. Thus, the log of 6·25 is 0·795880, which, divided by 0·01494, the log of 1·035, gives 52·27175, or 52 years 3 months 1 week, the time required.

This question was solved in the same manner, and the same answer obtained, by the proposer. We also received two other solutions from regular correspondents; but they will perceive, by the above solution, that they have mistaken the nature of the question.

A *sinking fund* is very different from a *single* sum of money improved at compound interest, with which the two gentlemen above alluded to have confounded it.

A sinking fund supposes that a sum equal to the original amount of the fund is added to the previous amount at the end of every year, and the whole again put out to interest.

QUESTIONS FOR SOLUTION.

QUEST. 49, *proposed by* Q. Q. *Portsea.*

Given the apparent altitude of the sun's centre, with his declination, and the angle at the zenith between the vertical circle passing over the sun, and that passing over a distant object in the horizon, together with the declination of the object: to find the latitude of the place of observation.

QUEST. 50, *proposed by* MR. J. M. EDNEY, *Clerkenwell.*

The side of an equilateral triangle, (the base of which falls on the diameter, and its vertex in the middle of the arc of a semi circle) may be found by multiplying one third of the diameter by the square root of 3. Required the analytical demonstration.

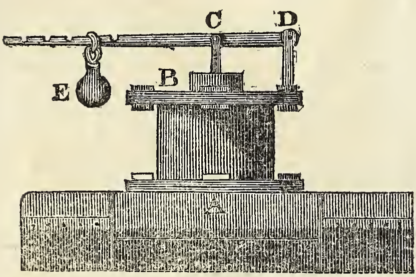
PNEUMATICS.

STEAM ENGINE.

In our last article on Pneumatics, we gave a short account of the progress of steam navigation, and of the manner in which steam is applied in this species of navigation; and having previously described some of the ancient, as well as the modern steam engines, and exhibited drawings of them, as well as of their principal parts, it only remains for us to give a description of that part of high-pressure engines, termed the safety valve. This is perhaps the more necessary, as the employment of engines of this kind has given rise to much prejudice against the general use of them, not only for propelling vessels at sea, but for the movement of machinery on land.

The safety-valve being therefore an object of considerable importance, both as regards the utility of the engine, and the preservation of those connected with its management, considerable attention has been paid to its construction.

The first engine that was made by Captain Savery, had a steel-yard safety-valve, to let the steam fly off when it arrived at a dangerous degree of elasticity. The following figure will furnish a sufficiently accurate idea of this simple apparatus.



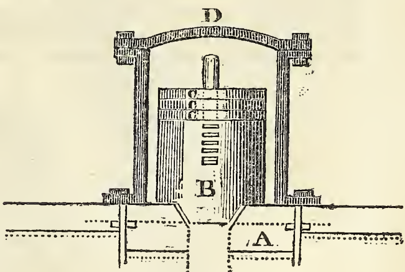
A, the top of the boiler; B, the safety-valve or plug, made to fit air tight in the tube or valve seat beneath; C, the lever working on an axis at D, and furnished with a moveable weight E, adjusted to balance the pressure of the steam.

When steam of considerable elasticity is required, the weight is placed at the extremity of the lever, and as such acts with greater force on the safety-valve, than when removed to a point nearer to the axis on which it revolves. So that should low-pressure steam be required, it will only be necessary to remove it nearer the axis or centre, and *vice versa*.

The lever and balance ball which form this apparatus, would at all times be effectual, were they not liable to be fastened by the corrosive nature of the materials of which the valve is composed, and, what is worse, their pressure altered by the addition of more weight. This, however, as too frequent experience has shown, is continually the case, the engineer having more regard for the full performance of his machine, than for his own safety; and to the overloading of this valve, accidents may be principally attributed.

To prevent a recurrence of those accidents which first drew the attention of the legislature to this important part of the engine, and to which we have already referred, under the head of steam navigation, it appears advisable to inclose the safety-valve in an iron box, and so put it beyond the control of the engine-man.

The annexed figure represents an inaccessible safety-valve, calculated to answer all the purposes for which it is intended; namely, the preservation of those employed in the neighbourhood of the boiler, and economy in the use of steam.

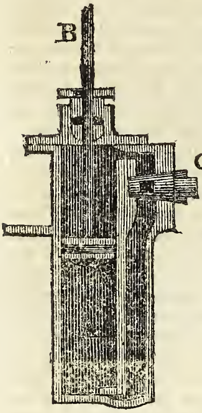


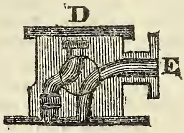
In this, as in the preceding diagram, A represents the boiler, and B the safety-valve, furnished with a small upright staff, on which slide the additional weights C C C. The whole is inclosed in a box D, pierced with holes to allow the steam to escape, after it has raised the valve B.

Should high pressure steam be wanted, it is necessary only to increase the number of weights, and the desired effect is produced; or if, on the contrary, steam of the usual atmospheric pressure be wanted, the whole of the weights are taken off.

Another safety-valve, opening internally, has, we believe, also been added by Messrs. Boulton and Watt. This is of great utility, more particularly in large engines, as it prevents the sides of the boiler being crushed in by the sudden introduction of water, or any artificial condensation that may take place, from reducing the heat of the boiler-head.

The *High-pressure Engine*, in its most simple form, may easily be understood by reference to the following diagram.





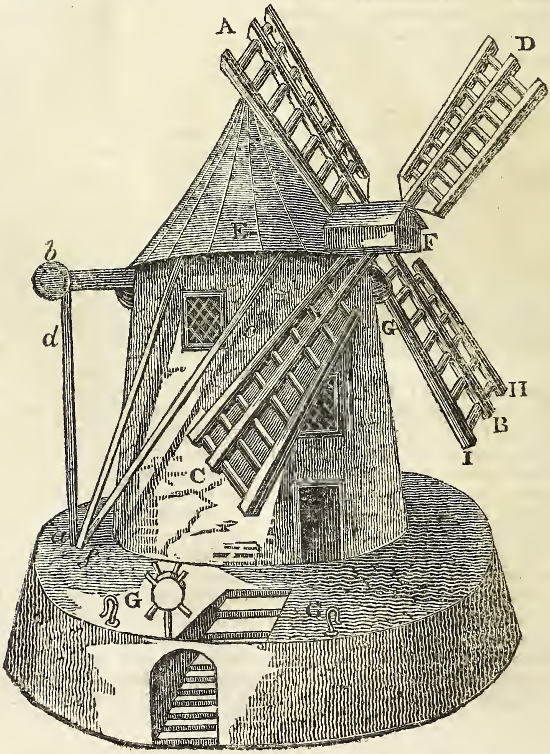
The cylinder A is furnished with a piston and rod B, the latter being made to fit air tight in a stuffing box at the top of the cylinder. A four-way cock C is also provided for the admission of highly elastic vapour, and its subsequent discharge into the atmosphere. The action of the four-way cock will be best understood by the section D; in which E represents the waste-pipe connected with the chimney, while two other apertures serve to convey the steam alternately to the upper and under side of the piston, and a third communicates with the steam-boiler. So that if we suppose the piston to be in an ascending direction, and the steam of course entering the cylinder beneath, a communication will at the same time be formed between the upper side of the piston and the atmosphere, while the steam that had previously been employed to depress the piston is now allowed to escape. When the piston has reached the top of the cylinder, the cock is turned, and its action reversed, the steam now entering above the piston, while a communication is formed for its escape beneath.

With these observations we shall conclude the subject of the steam engine.

WIND-MILL.

The internal structure of the *wind-mill* is much the same with that of water-mills. The difference between them lies chiefly in an external apparatus, for the application of the power.

This apparatus is represented by the following figure,



which consists of an axis EF, with two arms AB and CD passing through it, and intersecting each other at right angles in E, whose length is usually about 32 feet: on these yards are formed a kind of sails, vanes, or flights, in the figure of trapeziums, with parallel bases; the greater whereof, HI, is about six feet; and the less, FG, determined by radii drawn from the centre E, to I and H.

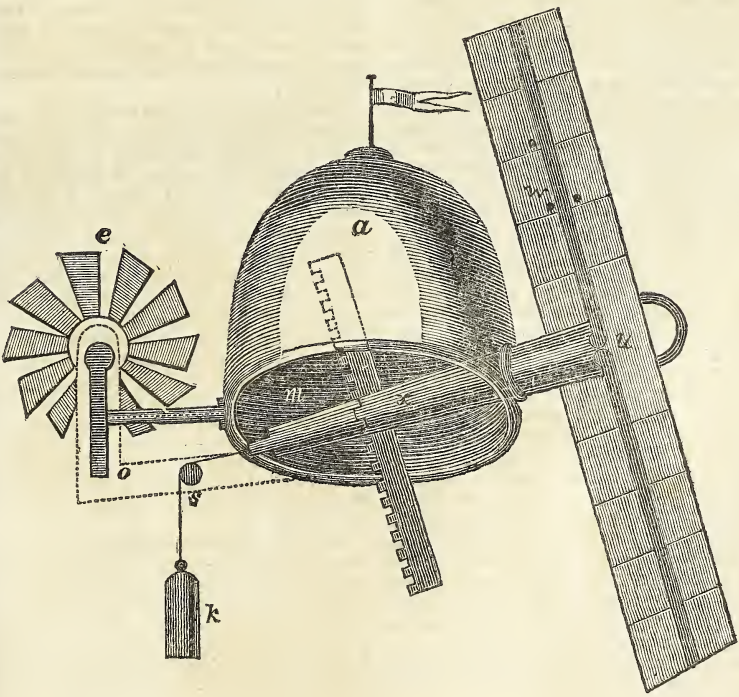
These sails are capable of being turned always to the *wind*, that they may receive its impression: in order to which there are two different contrivances, which constitute the two different kinds of *windmills* in use.

In the one the cover or roof only, with the axis and sails, turn round; and to accomplish this more easily, the roof is built in the shape of a turret or tower, as in the foregoing figure.

This tower is encompassed by a wooden ring, wherein is a groove, at the bottom of which are placed, at certain distances, a number of brass truckels; and within the groove is another ring, upon which the whole turret stands. To the moveable ring are connected beams *a b*, and *f c*; and to the beam *a b* is fastened a rope *b*, which, at the other extreme thereof, is fitted to a windlass or axis, in peritrochio: this rope being drawn through the iron hook G, and the windlass turned, the sails will be moved round, and put in the direction required.

In the other form of the machine, the whole is sustained upon a moveable arbor, or axis, perpendicular to the horizon, on a stand or foot; and by means of a lever, may be turned as occasion may require.

The following figure represents a machine of this kind, which is capable of being turned so as to face any wind, by



having its top or dome sustained on friction rollers. The ease, therefore, with which the sails, the axle, and cog-wheel, contained in the dome *a*, can be turned to the wind, depends on these, and the numerous powers of the fly-wheel *e*. This wheel consists of a number of triangular thin boards, each forming an angle of 45° with the plane of the wheel. On the axle of this wheel is a thread or screw, which fits into the teeth of the wheel *o*, and gives motion to it; this wheel turns on an axle, whose pivot is in the support, denoted by the dotted lines, and its other end is in a socket fastened in the dome: on this axle is the pinion *z*, which turns in a fixed contrate wheel, on the wall plate of the mill. When the wind changes from the principal sails, it instantly puts the fly-wheel *e* into motion; this turns the wheel *o*, whose pinion *z*, not being able to turn the fixed wheel on the wall, is turned itself, and with it the sails, the dome, and all that it contains: this effect continues till the fly-wheel gets into the lee of the dome: it then ceases, and the sails being brought to face the wind, are put into motion. Hence such a mill always turns itself to the wind, preventing the care of servants. The great sails produce an equal motion in a high or low wind, by being clothed with half-inch boards instead of canvass: these little doors are pushed open by a strong gale, and they shut when the wind is weak; so that by playing with the momentary inequalities of the wind, a quantity of surface is always presented in proportion to the impulses of it. A pin is stuck into the corner of each door, as at *w*, and all the pins are united to a cord, which, passing over the pulleys *u*, is fastened to a wire *x*, going through the axle *m*: on the other end of this wire is a nut, turning in the resisting part of the crooked lever *s*; so that the motion of the sails does not interrupt the operation of the weight *k*, which can be made greater or less, according to the speed the mill should go with. That the wind may have its full effect upon the sails, one sail should not pass into the place of another before the wind has resumed its regular current; for, in acting upon inclined planes, it is interrupted, and obliged to push by, and give an impulse to every sail in its passage; hence it is found that five sails are a *maximum*; that is, they are better than either four or five.

Horizontal wind-mills are weak, in comparison of those whose arms are inclined planes; for, by giving way, or falling back from the impulse of the wind, like a ship, the power is not half what it is against a plane that stands firm against the wind. But the advantage of going round always the same way, with every wind without attendance, may, in some cases, be thought adequate to the want of power, the vast expense of building, and the unsightly tower employed in the other kinds.

In order to conceive how the wind operates upon the sails of a wind-mill, and communicates motion to the machinery, it is necessary to understand something of the composition and resolution of forces.* A body moving perpendicularly against any surface, strikes it with all its force. If it move parallel to the surface, it does not strike it at all; and if it move obliquely, its motion being compounded of the perpendicular and parallel motion, only acts on the surface, considered as it is perpendicular, and only drives it in the direction of the perpendicular. So that every oblique direction of a motion is the diagonal of a parallelogram, whose perpendicular and parallel directions are the two sides. The angle which the sails ought to form with their common axis, so that the *wind* may have the greatest effect, is a matter of nice enquiry, and has engaged the attention of several eminent mathematicians.

Supposing the sail of a wind-mill to be a plane, the effect of the wind to turn the sail, in a plane at right angles to its axis, will be the greatest when the plane or sail makes an angle of 54° 44′, with the direction of the wind; consequently the inclination of the sail to the plane of its motion, or what is called the angle of *weather*, is 35° 16′.

This is true only when the sail is at rest, or just beginning to move. When the sail is in motion, and especially at the extremity where the motion is quickest, the wind strikes the sail under a far less angle than at the centre, and therefore the angle of weather must be less. Maclaurin has given a formula for calculating this angle; which makes it vary from 26° 34′ at the point of the sail nearest the centre, to 9° at its extremity.

From Mr. Smeaton's experiments it appears, that a wind-mill works to the greatest advantage when it is so constructed, that the velocity of the sails, is to their velocity when they go round without any load, as a number between 6 and 7 is to 10; and also that the load, when the mill works in this manner, is to the load that would just keep it from moving, nearly as 8·5 to 10.

With the different velocities of wind, the load that gives the maximum effect, varies nearly as the square of the velocity of the wind, and the effect itself as the cube.

The effect is always measured by the product of the velocity of the load into its weight. The velocity of the load varies in the simple and direct ratio of the velocity of the wind.

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* See pages 24 and 51.

OPTICS.

ON THE TREMORS OF REFLECTING TELESCOPES.

Every person who has been in the practice of using Reflecting Telescopes of high magnifying powers, must have been struck with the imperfection of vision arising from the tremors with which they are affected. During Dr. Maskelyne's long experience, he always found that the reflecting telescopes at Greenwich; viz. a Gregorian of two feet, and a Newtonian of six feet, showed the celestial objects indistinctly, and were considerably affected with tremors, when the 46-inch triple achromatic telescope showed them almost entirely free from them, and generally more distinct and better than even the six feet reflector. He observed the same effect in viewing land objects. Upon requesting the Rev. Mr. Edwards, however, to investigate the cause of this great defect, that ingenious individual undertook the task, and completely succeeded, not only in detecting the cause of these tremors, but in discovering a remedy for them. These causes were the springs which were employed to press the telescope into its cell, and the small eye-hole which was always used in reflectors. By removing, therefore, the springs at the back of the great speculum, and supporting the speculum on two pieces of card, wedged into its cell, about 45° on each side of its lowest point, and by taking away entirely the eye-hole in the Greenwich Newtonian reflector, Dr. Maskelyne found it so much improved, as to show a printed paper sensibly better and more distinct than the 46-inch achromatic telescope, which was formerly so superior to it.

When the specula of reflectors are made to rest on their lowest point, the weight of the metal bends the speculum in a small degree, and injures its figure. "This," says Mr. Edwards, "may appear strange; but I can at any time totally spoil the figure of a metal, by wedging it only with the thickness of a bit of common writing paper." Dr. Smith says, "*one thousandth* of an inch will spoil its figure. I am sure, also, *that* quantity, if not *less*, will injure it."

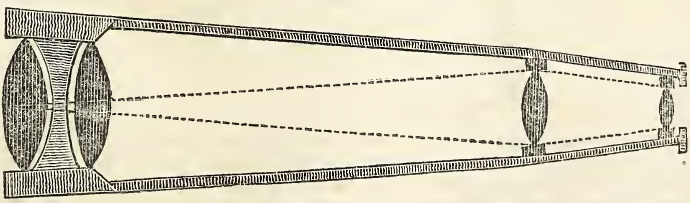
From this observation we think it quite evident, that if the speculum of a moderate size was bent, by resting on its lower point, a speculum of a larger size, must also be bent when supported at the two points above mentioned. We would, therefore, strongly recommend to the artist, not to allow the edge of his specula to rest on any point at all, but to fix them by their back, either to a plate of brass, or a frame, so as to be suspended, as it were, by every part of their posterior surface.

ACHROMATIC TELESCOPE.*

As *achromatic telescopes* differ only from those of the common refracting kind, in the formation and combination of the glasses employed in their construction; we did not think it necessary, in our definition of the different kinds of telescopes, at page 265, to notice the varieties of the two kinds there mentioned. But having now described the form and construction of the most approved instruments, both of the refracting and reflecting kind, we shall here endeavour to explain the nature and properties of the achromatic telescope.

In viewing objects through a refracting telescope, which is not furnished with an achromatic object glass, a kind of aberration is produced, by the different refrangibilities of the various coloured rays of light which form an infinite number of images, neither agreeing perfectly in situation nor in magnitude, so that the objects are rendered indistinct, by an appearance of colours at their edges: this imperfection, however, Mr. Dolland has in great measure obviated, by his achromatic object glasses: the construction of which depends on the important discovery that some kinds of glass separate the rays of different colours from each other, much more than others, while the whole deviation produced in the pencil of light, is the same. Mr. Dolland therefore combined a concave lens of flint glass, with a convex lens of crown glass, and sometimes with two such lenses.

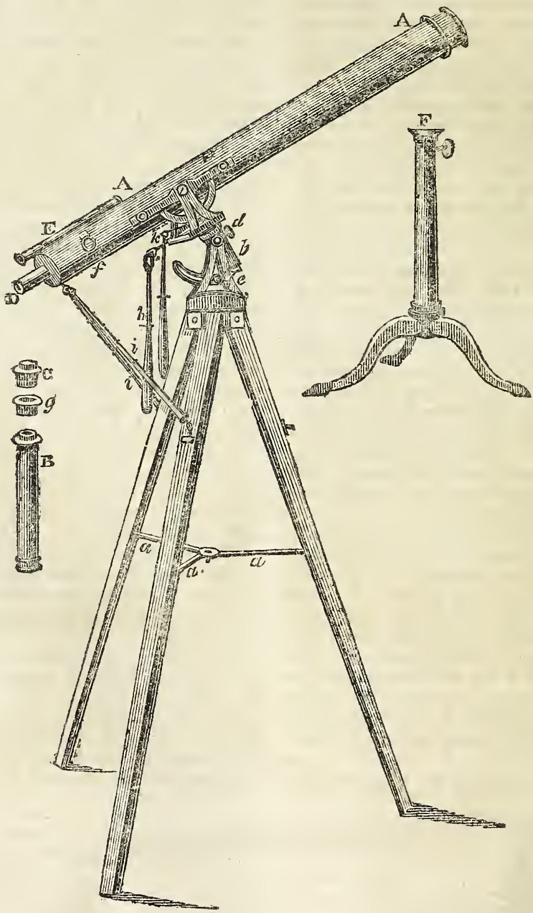
The following figure represents an achromatic telescope with a triple object glass, and with Boscovich's achromatic eyepiece, consisting of two similar lenses, one of which is every way three times as great as the other, their distance being twice the focal length of the smaller.



* A *lens* or *prism* is said to be *achromatic*, if it form an image *free from colour*, or if it refracts all the rays of white light to one focus. A compound lens may be made *achromatic*, or nearly free from colour, if it consists of two lenses formed of substances of different dispersive powers, the one being *convex* and the other *concave*, and having their focal lengths proportional to their dispersive powers.

The concave lens of flint glass was sufficiently powerful to correct the whole dispersion of coloured light produced by the crown glass, but not enough to destroy the effect of its refraction, which was still sufficient to collect the rays of light into a distant focus. For this purpose it is necessary that the focal lengths of the two lenses should be in the same proportion as the dispersive powers of the respective substances, when the mean deviations of the pencils are equal; that is, in the case of the kinds of glass commonly used nearly in the ratio of 7 to 10. Sometimes also the cromatic aberration; that is, the error arising from the different refrangibilities of the different rays, is particularly corrected in an eye piece, by placing a field glass in such a manner, as considerably to contract the dimensions of the image formed by the least refrangible rays, which is nearest to the eye glass, and to cause it to subtend an equal angle to the image formed by the most refrangible rays, this image being little affected by the glass.

The following figure represents one of Mr. Dolland's achromatic telescopes, supported in the centre of gravity, with its rack work motions, and mounted on its mahogany stand,



the three legs of which are made to close up together by means of the brass frame *a a a*, which is composed of three bars, connected together in the centre piece by three joints, and also to the three legs of the mahogany stand by three other joints, so that the three bars of this frame may lie close against the insides of the legs of the mahogany stand when they are pressed together, for convenience of carriage.

The brass pin, under the rack work, is made to move round in the brass socket *b*, and may be tightened by means of the finger screw *d*, when the telescope is directed nearly to the object intended to be observed. This socket turns on two centres, by which means it may be set perpendicular to the horizon, or to any angle required in respect to the horizon, the angle may be ascertained by the divided arc, and then made fast by the screw *e*. If this socket be set to the latitude of the place at which the telescope is used, and the plane of this arc be turned on the top of the mahogany stand, so as to be in the plane of the meridian, the socket *b* being fixed to the inclination of the pole of the earth, the telescope, when turned in this socket, will have an equatorial motion, which is always very convenient in making astronomical observations.

Fig. 2 in the plate, represents a stand to be used on a table, which may be more convenient for many situations, than the large mahogany stand. The telescope, with its rack work, may be applied to either of the two stands, as occasion may require, the sockets on the top of both being made exactly of the same size. The sliding rods may be applied to the feet of the brass stand, so that the telescope may be used with the same advantages on one as on the other.

The tube A A may be made either of brass or mahogany, of three and half feet long. The achromatic object glass of three and half feet focal distance, has an aperture of two inches and three quarters.

The larger size is with a tube five feet long, and has an achromatic object glass of three inches and one quarter aperture.

The eye tube, as represented by B, contains four eye glasses to be used for day, or any land objects. There are three eye tubes, as C, which have two glasses in each, to be used for astronomical purposes. These eye tubes all screw into the short brass tube at D. By turning the button or milled head at *f*, this tube is moved out of the larger, so as to adjust the eye glasses to the proper distance from the object glass, to render the object distinct to any sight, with any of the different eye tubes.

The magnifying power of the three-and half-feet Telescope, with the eye tube for land objects, is forty-five times, and of the five-feet for land objects, sixty-five times. With those for astronomical purposes, with the three and-half-feet, the magnifying powers are eighty, one hundred and thirty, and one hundred and eighty; and for the five feet, one hundred and ten, one hundred and ninety, and two hundred and fifty times.

Stained glasses, as *g*, are applied to all the different eye tubes, to guard the eye in observing the spots on the sun. These glasses are to be taken off when the eye tubes are used for other purposes.

The rack work is intended to move the telescope in any direction required, and is worked by means of the two handles at *h*. When the direction of the tube is required to be considerably altered, the worm-screws which act against the arc and the circle must be discharged: then the screw *d* being loosened, the pin of the rack work will move easily round in the socket *b*.

For the more readily finding or directing the telescope to any object, particularly astronomical objects, there is a small tube or telescope, called the finder, fixed near the eye-end of the large telescope. At the focusof the object glass of this finder, there are two wires, which intersect each other in the axis of the tube, and as the magnifying power is only about six times, the real field of view is very large; therefore any object will be readily found within it, which being brought to the intersection of the wires, it will then be within the field of the telescope.

In viewing astronomical objects, (and particularly when the greatest magnifying powers are applied) it is very necessary to render the telescope as steady as possible; for that purpose there are two sets of brass sliding rods, *i i*, as represented in the figure. These rods connect the eye-end of the telescope with two of the legs of the stand, by which any vibrations of the tube that might be occasioned by the motion of the air or otherwise, will be prevented, and the telescope rendered sufficiently steady for using the greatest powers. These sliding rods move within one another with so much ease, as to admit of the rack-work being used in the same manner, as if they were not applied.

CHEMISTRY.

OF THE METALS.

At the period when the existence of a number of brittle metallic matters was ascertained, and it was admitted, that all their properties approach those of the ductile metals, these began to be distinguished by the terms, semi-metals, as if ductility were the most essential character of these bodies in nature, as it is in the uses of art. Man, therefore, referring every thing to himself, and his events, gave to these bodies a determinate rank and place from their utility to himself. Another idea, less reasonable, no doubt, tended to confirm this expression of the semi-metals. The alchemists imagined that all the metals were only efforts of nature towards the production of gold, considered as the most perfect of metals, and that, by a subterraneous operation of nature, inimitable by art, they were capable of arriving at a state of maturity and perfection so as to become gold; and that all the metals were only successive states from a less to a greater degree of perfection, unto the last state, namely, aurification. Now, as ductility is one of the most prominent characters of gold, and the metals properly so called approach more or less to it by this character; those metals which did not possess it, appeared to them to be the first essays of nature, the embryos or metallic germs not yet developed. Hence, the expression of semi-metals to designate such bodies as had not undergone more than a semi-metallization.

But the slightest reflection is sufficient to show, that the application of the same idea must have led to the distinction of third parts of metals, and metallic fractions which might express the ratio or proportion of metallic properties which each of these bodies appeared comparatively to possess. This supposition shows the falsity of the expression of semi-metals, for it shows, that while it is defective as a true term of comparison to express the proportion of the metallic properties, chemistry would admit an erroneous and ridiculous language, by supposing, that the metals might in that manner pass from one to the other conversion; a conversion, which art has never been able to effect, nor can it be shown by any observation, to have been effected in the processes of nature.

It is no less evident, that we may apply the same remarks to the words *imperfect metals*, which was adopted to denote such metals as easily lose their metallic properties, and could not be again reduced to the metallic state without the addition of some combustible substance. The same may be said of *perfect metals*, a name given to those whose calces (oxides) were reducible by the mere application of heat. This expression depends still more on the imaginary transmutation, than the former term of semi-metals; since they affirm a pretended perfection in the one, and an imperfection in the other, which supposes a power of coming to perfection, and arriving at the state of the former.

Rejecting, therefore, these hypothetical terms infected with the opinions of the alchemists, and aware of the necessity of arranging the metals methodically, it became requisite, that distinctions should be admitted among them, derived from properties easily appreciated and compared with each other.

This is, however, by no means an easy task; for the relations of these bodies to the various objects of Chemisty are so complex and diversified, that their classification becomes a matter of considerable difficulty; and we may safely assert, that no arrangement which has yet been made of these interesting bodies is wholly free from objection; nor do we pretend to introduce one, which has any peculiar claims to superiority, in this respect, over those that are generally received among the Chemists of the present day.

The celebrated French Chemist, Fourcroy, divides the metals into five orders or classes. 1. The *brittle and acidifiable*, includes four species; viz. arsenic, tungsten, molybdena, and chrome. 2. The *brittle and simply oxydizable* are seven; titanium, uranium, cobalt, nickel, (since shown by Richter not to belong to this division,) manganese, bismuth, antimony, and tellurium. 3. The metals that are *oxydizable and imperfectly ductile*, are mercury and zinc. 4. The *ductile and easily oxydizable*, tin, lead, iron, and copper. 5 The *very ductile, and difficult of oxydizement*, are silver, gold, and platina.

Another still more generally-followed arrangement is that of Dr. Thomson, who divides them into four classes. The first class comprehends the MALLEABLE METALS, which are the following: gold, platina, silver, mercury, palladium, rhodium, iridium, osmium, copper, iron, nickel, tin, lead, and zinc. The second class includes the BRITTLE AND EASILY FUSED; viz. bismuth, antimony, tellurium, and arsenic. The third class, metals that are BRITTLE AND DIFFICULTLY FUSED: these are cobalt, manganese, chrome, molybdena, uranium, and tungsten. The fourth class are termed REFRACTORY METALS, because they have never yet been exhibited in a separate form, but always in combination with oxygen. These are titanium, columbium, tantalium, cerium, and some others.

"By arranging metals," says Dr. Ure, "according to the degree in which they possess the obvious qualities of unalterability, by common agents, tenacity, and lustre, we also conciliate their most important chemical relations; namely, those to oxygen, chlorine, and iodine; since their metallic pre-eminence is, popularly speaking, inversely as their affinities for these dissolvents. In a strictly scientific view, their habitudes with oxygen should perhaps be less regarded in their classification, than with chlorine; for this element has the most energetic attractions for the metals. But, on the other hand, oxygen, which forms one-fifth of the atmospheric volume, and eight-ninths of the aqueous mass, operates to a much greater extent among metallic bodies, and incessantly modifies their form, both in nature and art." Now the arrangement we have adopted in the following list of these bodies, will indicate very nearly their relations to oxygen. As we progressively descend, the influence of that beautiful element progressively increases. Among the bodies near the top of the table, its powers are subjugated by the metallic constitution; but among those near the bottom, it exercises an almost despotic sway, which Volta's magical pile, directed by the genius of Davy, can only suspend for a season. The emancipated metal soon relapses under the dominion of oxygen.

The number of metals at present known amount to thirty, if we except the bases of the Alkalies and Earths, and one or two other substances, which some individuals wish to rank among these bodies; but as they are not generally acknowledged to belong to this class of substances, we shall not include them in the following table.

GENERAL TABLE OF THE METALS.

NAMES.	Spe.Gra.	Precipitants.
1 Platinum	21·47	Mar. ammon.
2 Gold	19·30	Sulph. iron / Nitr mercury
3 Silver	10·45	Common salt
4 Palladium	11·8	Prus. mercury
5 Mercury	13·6	Common salt / Heat
6 Copper	8·9	Iron
7 Iron	7·7	Succin. soda, with perox.
8 Tin	7·29	Corr. sublim.
9 Lead	11·35	Sulph. soda
10 Nickel	8·4	Sulph. potash?
11 Cadmium	8·6	Zinc
12 Zinc	6·9	Alk. carbonates
13 Bismuth	9·88	Water
14 Antimony	6·70	Water / Zinc
15 Manganese	8·	Tartr. pot.
16 Cobalt	8·6	Alk. carbonates
17 Tellurium	6·115	Water / Antimony
18 Arsenic	8·35? / 5·76?	Nitr. lead
19 Chromium	5·90	Do.
20 Molybdenum	8·6	Do.?
21 Tungsten	17·4	Mur. lime?
22 Columbium	5·6?	Zinc, or inf. galls
23 Selenium	4·3?	Iron / Sulphite amm.
24 Osmium	?	Mercury
25 Rhodium	10·65	Zinc?
26 Iridium	18·68	Do.?
27 Uranium	9·0	Ferropr. pot.
28 Titanium	?	Inf. galls
29 Cerium	?	Oxal. amm.
30 Wodanium	11·47	Zinc
31 Potassium	0·865	Mur. plat. / Tart. acid.
32 Sodium	0·972	
33 Lithium		
34 Calcium		
35 Barium		
36 Strontium		
37 Magnesium		
38 Yttrium		
39 Glucinum		
40 Aluminum		
41 Thorinum		
42 Zirconium		
43 Silicium		

The first 12 metals in the table are malleable, as also the 31st, 32d, and 33d, in their solid or congealed state.

The first 16 are capable of being converted into oxides, which are neutral salifiable bases.

Those marked 17, 18, 19, 20, 21, 22, and 23, are capable of being acidified, by combination with oxygen.

Of the oxides of the rest to the 31st, very little is known.

The others form with oxygen, the alkaline and earthy bases.

Having given as full a list of the metals as it is possible to obtain, and having stated pretty fully their general and characteristic properties, we shall now begin to describe them individually, and to state their particular properties. The malleable metals, being the most valuable as well as the most useful, we shall begin by describing them first.

OF GOLD.

Gold seems to have been known from the very beginning of the world. Its properties and its scarcity have rendered it more valuable than any other metal.

It is of an orange red, or reddish yellow colour, and has no perceptible taste or smell. Its lustre is considerable, yielding only to that of platinum, steel, silver, and mercury.

Its specific gravity is 19·3.

No other substance is equal to it in ductility and malleability. It may be beaten out into leaves so thin, that one grain of gold will cover $56\frac{3}{4}$ square inches. These leaves are only $\frac{1}{282000}$ of an inch thick. But the gold leaf with which silver wire is covered is only $\frac{1}{12}$ of that thickness. An ounce of gold, upon silver wire, is capable of being extended more than 1300 miles in length.

Its tenacity is considerable; though in this respect it yields to iron, copper, platinum, and silver. From the experiments of Sickingen, it appears that a gold wire 0·078 inch in diameter, is capable of supporting a weight of 150·07 lbs. avoirdupoise, without breaking.

It melts at 32° of Wedgewood's pyrometer.* When melted, it assumes a bright blueish green colour. It expands in the act of fusion, and consequently contracts while becoming solid more than most metals; a circumstance which renders it less proper for casting into moulds.

It requires a very violent heat to volatilize it; it is therefore, to use a chemical term, exceedingly *fixed.* Gasto Claveus

* According to the calculation of the Dijon academicians, it melts at 1298° Fahrenheit; according to Mortimer, at 1301°.

informs us, that he put an ounce of pure gold in an earthen vessel, into that part of a glass-house furnace where the glass is kept constantly melted, and kept it in a state of fusion for two months, yet it did not lose the smallest portion of its weight. Kunkel relates a similar experiment attended with the same result; neither did gold lose any perceptible weight, after being exposed for some hours to the utmost heat of Mr. Parker's lens. Homberg, however, observed, that when a very small portion of gold is kept in a violent heat, part of it is volatilized. This observation was confirmed by Macquer, who observed the metal rising in fumes to the height of five or six inches, and attaching itself to a plate of silver, which it gilded very sensibly; and Mr. Lavoisier observed the very same thing when a piece of silver was held over gold melted by a fire blown by oxygen gas, which produces a much greater heat than common air.

After fusion, it is capable of assuming a crystalline form. Tillet and Mongez obtained it in short quadrangular pyramidal crystals.

Gold is not in the least altered by being kept exposed to the air; it does not even lose its lustre. Neither has water the smallest action upon it.

It is capable, however, of combining with oxygen, and even of undergoing combustion in particular circumstances. The resulting compound is an *oxide of gold*. Gold must be raised to a very high temperature before it is capable of abstracting oxygen from common air. It may be kept red hot almost any length of time without any such change. Homberg, however, observed, that when placed in the focus of Tschirnhaus's burning glass, a little of it was converted into a purple-coloured oxide; and the truth of his observations were confirmed by the subsequent experiments of Macquer with the very same burning-glass. But the portion of oxide formed in these trials is too small to admit of being examined. Electricity furnishes a method of oxidizing it in greater quantity.

ASTRONOMY.

ON LIGHT.

Fairest of beings! first created light!
Prime cause of beauty! for from thee alone
The sparkling gem, the vegetable race,
The nobler worlds that live and breathe their charms,
The lovely hues peculiar to each tribe,
From thy unfading source of splendour draw
In thy pure shine, with transport I survey
This firmament, and these her rolling worlds,
Their magnitudes and motions. MALLET.

The nature of Light has been the subject of speculation and conjecture among philosophers, from the first dawnings of philosophy to the present day. But of all the conjectures which have been advanced on this curious and interesting subject, there is scarcely one supported by evidence sufficient to entitle it to preference over the other. There are, however, two opinions on this subject, which have prevailed more generally than any of the others, and therefore, it may be proper to notice them here, although the design of the present work is rather to state what is known respecting any phenomenon, than to indulge in conjectures concerning it.

The celebrated Huygens considered light as a subtle fluid filling space, and rendering bodies visible by the undulations into which it was thrown. According to this theory, when the sun rises it agitates this fluid, the undulations gradually extend themselves, and at last striking against our eyes we see the sun. This opinion of Huygens was adopted by Euler, one of the best mathematicians that ever lived, who exerted the whole of his consummate mathematical skill in its defence.

Sir I. Newton and many other distinguished philosophers consider light as a substance consisting of small particles, constantly separating from luminous bodies, moving in straight lines, and rendering other bodies luminous by passing from them and entering the eye. Newton has been at great pains to establish this theory, and has certainly shown that all the phenomena of light may be mathematically deduced from it.

While Huygens and Euler have attempted to support their hypothesis, rather by starting objections to Newton's, than by bringing forward direct proofs, Newton and his disciples, on the contrary, have shown that the known phenomena of light are *inconsistent* with the undulations of a fluid, and that on such a supposition, there can be no such thing as darkness at all. They have also brought forward a great number of direct arguments in support of their theory, which it has been impossible to answer.* But without giving a decided preference to any theory, we shall proceed to state some of its properties.

Roemer, a Danish astronomer, while engaged in making observations on the

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* M. Delavel maintains, that all light is reflected by white particles, and coloured in its transmission. No transparent medium reflects any light when examined within a blackened bottle; this is shown by experiments on 68 kinds of fluids, and on many kinds of glasses, and other substances. For this, and for the colours of the sea, M. Delaval proposes a very singular theory; but those who wish to become particularly acquainted with it, must consult his work on the permanent colours of opaque bodies.

satellites of Jupiter, found that in eclipses they emerged from the shadow at certain times a few minutes later, and at others a few minutes sooner than they ought to have done according to the tables, which had been previously constructed to show the times of their revolutions, eclipses, &c. On comparing these apparent irregularities together, he found that the eclipses happened before or after the computed time, according as the earth was nearer to or farther from Jupiter. Hence he formed the ingenious conjecture, which was soon demonstrated to be the case, that the motion of light is not instantaneous, as was then generally believed, but that it required a certain portion of time, to pass from the luminous body to the eye of the observer. According to Roemer's calculation, it was about *seven minutes* in traversing the radius of the earth's orbit; but it has since been found, that when the earth is exactly between Jupiter and the sun, his satellities are eclipsed about 8¼ minutes sooner than the time found by the tables; but when the earth is nearly in the opposite point, these eclipses happen about 8¼ minutes later than that determined by the tables. It is therefore concluded that light takes about 16½ minutes of time to pass over a space equal to the diameter of the earth's orbit, which is at least one hundred and ninety millions of miles; it therefore moves at the rate of nearly 200,000 miles per second, which is about 10,300 times faster than the earth in its orbit, and 1,550,0000 times quicker than a cannon ball.*

The velocity of light being known, it is easy to know the time it requires to arrive at the earth from any of the planets, or even the fixed stars, if their distance be known. For it has been ascertained, that the reflected light of the planets and satellites, travels with the same velocity as the direct light of the sun or fixed stars; and that the velocity is the same from whatever distance it comes.

The discovery of Roemer has been completely confirmed by another most important discovery made by our countryman, Dr. Bradley, while engaged in making a series of observations, with a view to determine the annual parallax of the fixed stars. This celebrated astronomer found that the aberration or difference between the true and apparent place of a fixed star, is occasioned by the progressive motion of light, combined with the motion of the earth in its orbit; and that this *aberration*, when greatest, amounted to 20″·232. Now the earth describes an arc of 20″·232, in 8′ 13″, the time that light takes to pass over the semidiamer of the earth's orbit. This circumstance, therefore, not only affords one of the most convincing proofs of the motion of the earth in its orbit, but entirely overthrows both the Ptolemaic and Tychonic systems, and completely establishes the motion of the earth.

As the rays of light are known to proceed only in straight lines from luminous bodies, and as the earth is constantly moving forward in its orbit, it is evident that a ray of light proceeding from any celestial body, will impinge on the earth at a different point from what it would have done had the earth been stationary. It is therefore necessary, in making astronomical observations with nicety, to make allowance for the aberration. When a fixed star or planet, for example, is seen through a tube or telescope, the tube does not point exactly to the *true* place of the star or planet, but to its *apparent* place, which is always more advanced in the direction we are moving than its true place, by a quantity equal to the aberration of the object.* But this will, perhaps, be better understood by the following illustration, which is given by M. Maupertuis in his Elements of Geography.

"The direction," says he, "in which a gun must be pointed to strike a bird in its flight, is not exactly that of the bird, but of a point a little before it, in the path of its flight; and that so much the more as the flight of the bird is more rapid, with respect to the flight of the shot. In this way of considering the matter, the flight of the bird represents the motion of the earth, and the flight of the shot the motion of the light proceeding from the object."

Many philosophers have attempted, not only to compare the light of the stars with that of the sun, but also to ascertain their distances by comparisons of this kind.

The Rev. Mr. Mitchell, in an elaborate and ingenious paper in the Transactions of the Royal Society, states, that our sun would still appear as luminous as the star Sirius, although removed to 400,000 times his present distance; and that the fixed stars cannot be nearer than this, if they be equal to the sun in lustre and magnitude, and that they are so is the opinion of the most celebrated astronomers of the present day. Euler, who has already been mentioned, makes the light of the sun equal to 6,500 candles at one foot distance; the moon equal to one candle at 7½ feet distance; Venus to one at 421 feet; and Jupiter to one at 1320 feet. From this comparison it follows, the light of the sun exceeds that of the moon 364,000

* The real time which light takes to pass from the sun to the earth is 8 minutes 13 seconds.

* The aberration not only affects the longitude of a star or planet, but also its altitude, declination, and right ascension.

times. It is therefore no wonder that the attempts which have been made by some philosophers to condense the light of the moon by lenses, have been attended with so little success. For, should one of the largest of these lenses even increase the light of the moon one thousand times, still, in this increased state, it will be three hundred and sixty-four times less than the intensisty of the common light of the sun.

The intensity of light has been found to vary as the square of the distance; for, if an object be placed one foot distant from a candle, it will receive four times more light than when it is removed to double the distance; nine times more than when it is removed to three times the distance, and so on.

OF THE ATMOSPHERE, AND ASTRONOMICAL REFRACTION.

The earth is surrounded by a thin fluid mass of matter, called the Air or Atmosphere, which revolves with it in its diurnal motion, and goes round the sun with it every year. This fluid is both ponderous and elastic. Its weight is known from the Torricilian experiment, or that of the barometer; and its elasticity is proved by simply inverting a vessel full of air in water.

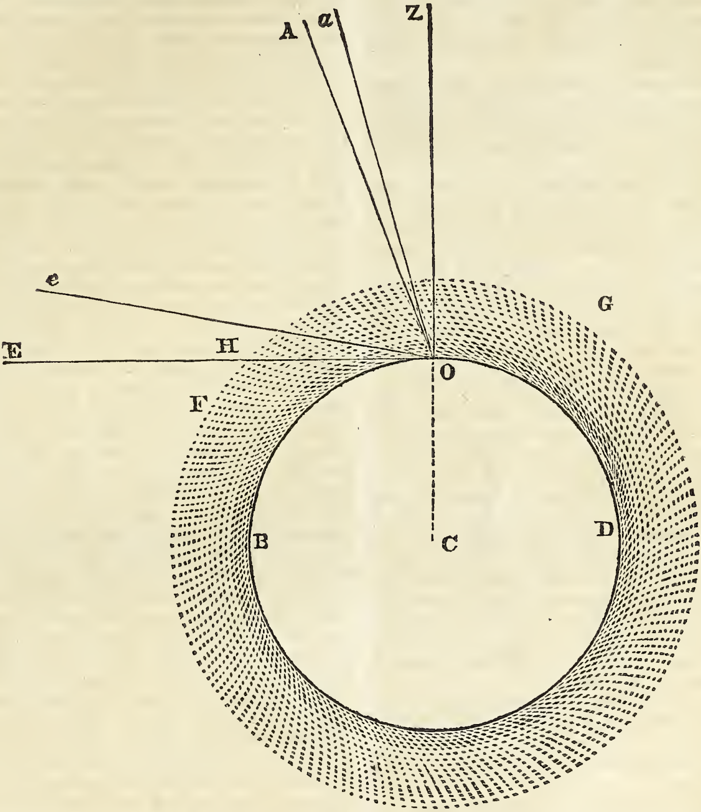
The atmosphere at the earth's surface being pressed by the weight of all above it, is there pressed the closest together; and therefore the atmosphere is densest of all at the earth's surface; and its density necessarily diminishes the higher up. For each stratum of air is compressed only by the weight of those above it; the upper strata are therefore less compressed, and consequently less dense, than those below them.

The pressure or weight of the atmosphere has been repeatedly determined, by various experiments, to be about fourteen pounds on every square inch of the earth's surface. Hence, the total pressure on the whole surface of the earth is 10,686,000,000 hundreds of millions of pounds avoirdupoise.

From a number of experiments made on the density of the atmosphere, at various altitudes, by means of the barometer, it has been ascertained, that if heights, from the earth's surface, be taken in arithmetical progression, the density of the corresponding strata of air decreases in geometrical progression. Thus the density of the atmosphere is reduced one-half for every $3\frac{1}{2}$ miles of perpendicular ascent. At seven miles in height, the corresponding density is only one-fourth: at $10\frac{1}{2}$ miles, one eighth; and 14 miles, one-sixteenth: and so on. Since the density of the air decreases at this rapid rate, it is evident that at a very moderate distance from the surface of the earth, its density would be so much diminished, as to render it incapable of sustaining animal life. From observation and experiment, it is pretty well known that 45 or 50 miles is the utmost height at which the density is capable of refracting a ray of light; and, therefore, this may be considered the altitude corresponding to the least *sensible* degree of density: for, according to the law of its decrease, just stated, the density at this altitude is above 10,000 times less than at the earth's surface.

One of the most extraordinary and useful properties of the atmosphere, is its reflective power, which causes the heavens to appear luminous when the sun shines; for were it not for this power, the whole of the heavens, and every thing on the earth, would appear black, or completely dark, except what the sun's rays directly impinged upon. The stars would be visible by day as well as by night; and we could see nothing except what was fully exposed to the sun. There could be no twilight, and, consequently, the blackest darkness would immediately succeed the brightest sun-shine when the sun sets; and the transition would be equally sudden from the blackest darkness to the brightest sunshine when the sun rose. But by means of the atmosphere we enjoy the sun's light, reflected from the aërial particles for some time before he rises, and also for some time after he sets. For when the earth, by its revolution on its axis, has turned any particular place away from the sun, the atmosphere above that place will continue to be illuminated for some time. However, as the sun gets farther below the horizon, the less will the atmosphere be illuminated; and when he is *eighteen* degrees under the horizon, it ceases to be illuminated, and then all that part of the heavens which is over the place will become dark: for the place will then be turned too far from the sun, and his rays will strike too high on the atmosphere to be refracted or bent downwards at that place. In consequence of the refractive power of the atmosphere, all the heavenly bodies appear higher than they really are: for, on account of the variation in the density of the air, a ray of light in passing through it will be refracted at every instant, and consequently the path of the ray will be a curve. And as an object is always seen in the direction in which the rays of light proceeding from it enter the eye, it is evident every celestial body will appear more elevated above the horizon than it actually is, by a quantity equal to the refraction which a ray of light suffers in passing from it through the atmosphere to the eye of the observer.

When the object is in the zenith, the refraction is quite insensible; but it increases as the altitude of the object diminishes, till it reaches the horizon, and then the refraction is greatest; for the rays which proceed from the object, in that situation, enter the atmosphere more obliquely than in any other, and consequently are more turned out of their course. This will be evident from an inspection of the following figure.



Where B O D represents the surface of the earth, O the place of an observer, and F G H the surrounding atmosphere. A ray of light proceeding from a body, Z, in the zenith, is not refracted; but if it proceed from a body at A, it will enter the eye at O, and appear in the direction O *a*; if the body be in the horizon, as at E, the rays proceeding from it will enter the eye at O, and appear to come in the direction *e* O.

On some accasions, the horizontal refraction amounts to 36 or 37 minutes, and, generally, to about 33 minutes, which is equal to the diameter of the sun or moon; and therefore the whole disc of the sun or moon will appear above the horizon, both at rising and setting, although actually below. This is the reason that the full moon has sometimes been seen above the horizon before the sun was set. A remarkable instance of this kind was observed at Paris, on the 19th of July, 1750, when the moon appeared visibly eclipsed, while the sun was distinctly to be seen above the horizon.

At some seasons of the year the sun appears ten minutes sooner above the horizon in the morning, and continues as much longer above it in the evening, than he would do were there no refraction; and at a mean rate, about seven minutes on any day of the year. The refraction varies, however, very much with the state of the atmosphere. In cold dry weather the air is more dense than in warm weather; consequently the refraction is greater in cold weather than in warm; and for the same reason, it is greater in cold countries than in hot ones.

A remarkable instance of this is mentioned by Dr. Smith in his Optics, where he states, that some Hollanders who wintered in Nova Zembla, in the year 1596, were surprised to find that, after three months' constant darkness, the sun began to appear seventeen days sooner than the time by computation deduced from the latitude, which was 76 degrees. Now this phenomenon can only be accounted for by the extraordinary refraction of the sun's rays in passing through the cold dense air in that climate.

At the same altitudes, the sun, moon, and stars, all undergo the same refraction; for at equal altitudes, the rays which proceed from any of these bodies suffer the same inclination.

The horizontal refraction being the greatest, causes the sun and moon, at rising and setting, to appear of an oval form; for the lower edge of each being seen through denser atmosphere than the upper edge, is more refracted; consequently, the perpendicular diameter must appear shortened, while the horizontal diameter, (which is not affected by refraction) remains the same, and in this way the oval appearance is produced. For the same reason, two fixed stars that are near the horizon, and right above each other, appear nearer than when they are high above the horizon; and if they are both in the horizon, but at some distance from each other, then they will appear at a less distance than they really are; for the refraction makes each of them higher, and consequently must bring them into parts of their respective vertical circles, which are nearer to each other, because all vertical circles converge and meet in the zenith. Hence, in all astronomical calculations allowance must be made for refraction, before the true altitude of any celestial body can be obtained. Tables, containing this allowance for all altitudes, are to be found in every work on practical astronomy.

The atmosphere not only occasions celestial bodies to appear higher than they really are, by bending the rays of light as they pass through it, but it also affects terrestrial bodies in the same way. The quantity of this refraction is, however, found to vary considerably with the different states of the atmosphere, and is therefore very uncertain. But at a mean rate it may be taken at one-fourteenth part of the distance expressed in degrees in a great circle: or, according to Professor Playfair, it is about one-seventh part of the correction for the earth's curvature, answering to the distance between the observer and the object.*

* For example, suppose the distance between a person and any conspicuous object to be 5 English miles, and he wishes to know how much it is elevated by refraction. The correction for the earth's curvature on this distance is $16\frac{2}{3}$ feet, one-seventh part of which is 2 feet $4\frac{1}{2}$ inches, which it is raised by refraction.

Miscellaneous Subjects.

MEMOIR OF DOCTOR FRANKLIN.

Benjamin Franklin, the celebrated American philosopher, was sprung, as he himself informs us, from a family settled for a long course of years in the village of Ecton, in Northamptonshire; where they had augmented their income, arising from a small patrimony of thirty acres of land, by adding to it the profits of a blacksmith's business. His father, Josias, having been converted by some nonconformist ministers, left England for America in 1682, and settled at Boston, as a soap-boiler and tallow-chandler. At this place, in 1706, Benjamin, the youngest of his sons, was born. It appeared at first to be his destiny to become a tallow-chandler, like his father; but, as he manifested a particular dislike to that occupation, different plans were thought of, which ended in his becoming a printer, in 1718, under one of his brothers, who was settled at Boston, and in 1721 began to print a newspaper. This was a business much more to his taste, and he soon shewed a talent for reading, and occasionally wrote verses, which were printed in his brother's newspaper, although unknown to the latter. He wrote also in the same some prose essays, and had the sagacity to cultivate his style after the model of the Spectator. With his brother he continued as an apprentice, until their frequent disagreements, and the harsh treatment he experienced, induced him to leave Boston privately, and take a conveyance by sea to New York. This happened in 1723. From New York he immediately proceeded, in quest of employment, to Philadelphia, not without some distressing adventures. His own description of his first entrance into that city, where he was afterwards in so high a situation, is too curious to be omitted.

"On my arrival at Philadelphia, I was in my working dress, my best clothes being to come by sea. I was covered with dirt; my pockets were filled with shirts and stockings; I was unacquainted with a single soul in the place and knew not where to seek for a lodging. Fatigued with walking, rowing, and having passed the night without sleep, I was extremely hungry, and all my money consisted of a Dutch dollar, and about a shilling's worth of coppers, which I gave to the boatmen for my passage. As I had assisted them in rowing, they refused it at first, but I insisted on their taking it. A man is sometimes more generous when he has little, than when he has much money; probably because, in the first case, he is desirous of concealing his property.

"I walked towards the top of the street, looking eagerly on both sides till I came to Market-street, where I met a child with a loaf of bread. Often had I made my dinner on dry bread. I enquired where he bought it, and went straight to the baker's shop which he pointed out to me; I asked for some biscuits, expecting to find such as we had at Boston, but they made, it seems, none of that sort at Philadelphia. I then asked for a threepenny loaf. They made no loaves at that price. Finding myself ignorant of the prices, as well as of the different kinds of bread, I desired him to let me have three pennyworth of bread of some kind or other. He gave me three large rolls. I was surprised at receiving so much. I took them, however, and having no room in my pockets, I walked on with a roll under each arm, eating the third. In this manner I went through Market-street to Fourth-street, and passed the house of Mr. Read, the father of my future wife. She was standing at the door, observed me, and thought, with reason, that I made a very singular and grotesque appearance."

Notwithstanding this unpromising commencement, Franklin soon met with employment in his business, working under one Keimer, a very indifferent printer, though at that time almost the only one in Philadelphia. In 1724, encouraged by the specious promises of Sir William Keith, governor of the province, Franklin sailed for England, with a view of purchasing materials for setting up a press; though his father, to whom he had applied, prudently declined encouraging the plan, on account of his extreme youth, as he was then only eighteen. On his arrival in England, he had the mortification to find that the governor, who had pretended to give him letters of recommendation, and of credit for the sum required for his purchases, had only deceived him; and he was obliged to work at his trade in London for a maintenance. The most exemplary industry, frugality, and temperance, with great quickness and skill in his business, both as a pressman and as a compositor, made this rather a lucrative situation. He reformed the workmen in the houses where he was employed, which were, first, Mr. Palmer's, afterwards Mr. Watts's, in Wild-street, Lincoln's-Inn-fields, by whom he was treated with a kindness which he always remembered. Desirous, however, of returning to Philadelphia, he engaged himself as book-keeper to a merchant, at fifty pounds a year; "which," says he, "was less than I earned as a compositor." He left England, July 23, 1726, and reached Philadelphia early in October. In 1727, Mr. Denham, the merchant, died, and Franklin returned to his occupation as a printer, under Keimer, his first master, with a handsome salary. But it was not long before he set up for himself in the same business, in concert with one Meredith, a young man, whose father was opulent, and supplied the money required.

A little before this, he had gradually associated with a number of persons, like himself, of an eager and inquisitive turn of mind, and formed them into a club, or society, to hold meetings for their mutual improvement in all kinds of useful knowledge, which was in high repute for many years after. Among many other useful regulations, they agreed to bring such books as they had into one place, to form a common library; but this furnishing only a scanty supply, they resolved to contribute a small sum monthly towards the purchase of books for their use from London. In this way their stock began to increase rapidly; and the inhabitants of Philadelphia, being desirous of profiting by their library, proposed that the books should be lent out on paying a small sum for this indulgence. Thus, in a few years, the society became rich, and possessed more books than were perhaps to be found in all the other colonies; and the example began to be followed in other places.

About 1728 or 1729, Franklin set up a newspaper, the second in Philadelphia, which proved very profitable, and afforded him an opportunity of making himself known as a political writer, by his inserting several attempts of that kind in it. He also set up a shop for the sale of books and articles of stationary, and in 1730 he married a lady, whom he had courted before he went to England. He afterwards began to have some leisure, both for reading books, and writing them, of which he gave many specimens from time to time. In 1732, he began to publish "Poor Richard's Almanack," which was continued for many years. It was always remarkable for the numerous and valuable concise maxims which it contained, for the economy of human life; all tending to industry and frugality; and which were comprised in a well-known address, entitled "The way to Wealth." This has been translated into various languages, and inserted in almost every magazine and newspaper in Great Britain or America. It has also been printed on a large sheet, proper to be framed, and hung up in conspicuous places in all houses, as it very well deserves to be. Mr. Franklin became gradually more known for his political talents. In 1736, he was appointed clerk to the general assembly of Pennsylvania; and was re-elected by succeeding assemblies for several years, till he was chosen a representative for the city of Philadelphia; and in 1737 he was appointed post-master of that city. In 1738, he formed the first fire-company there, to extinguish and prevent fires, and the burning of houses; an example which was soon followed by other persons, and other places. And soon after, he suggested the plan of an association for insuring houses and ships from losses by fire, which was adopted; and the association continues to this day. In 1744, during a war between France and Great Britain, some French and Indians made inroads upon the frontier inhabitants of the province, who were unprovided for such an attack; the situation of the province, was at this time truly alarming, being destitute of every means of defence. At this crisis Franklin stepped forth, and proposed to a meeting of the citizens of Philahelphia, a plan of a voluntary association for the defence of the province. This was approved of, and signed by 1200 persons immediately. Copies of it were circulated throughout the province; and in a short time the number of signatures amounted to 10,000. Franklin was chosen colonel of the Philadelphia regiment, but he did not think proper to accept of the honour.

Pursuits of a different nature now occupied the greatest part of his attention for some years. Being always much addicted to the study of natural philosophy, and the discovery of the Leyden experiment in electricity having rendered that science an object of general curiosity, Mr. Franklin applied himself to it, and soon began to distinguish himself eminently in that way. He engaged in a course of electrical experiments with al the ardour and thirst for discovery which characterised the philosophers of that day. By these he was enabled to make a number of important discoveries, and to propose theories to account for various phenomena; which have been generally adopted, and which will probably endure for ages. His observations he communicated in a series of letters to his friend Mr. Peter Collinson; the first of which is dated March 28, 1747. In these he makes known the power of points in drawing and throwing off the electric matter, which had hitherto escaped the notice of electricians. He also made the discovery of a plus and minus, or of a positive and negative state of electricity; from whence, in a satisfactory manner he explained the phenomena of the Leyden phial, first observed by Cuneus, or Muschenbroeck, which had much perplexed philosophers. He shewed that the bottle when charged, contained no more electricity than before, but that as much was taken from one side as was thrown on the other; and that, to discharge it, it was only necessary to make a communication between the two sides, by which the equilibrium might be restored, and then no signs of electricity would remain.

[*To be continued.*]

SOLUTION OF QUESTIONS.

Quest. 48. *answered by* Mr. Whitcombe, *Cornhill.*

Put $a = 2{\cdot}943271$ and $m = 1{\cdot}94353929$. then by substitution and transposition, we have $x^3 - ax + m = o.$, and per Nicholas Tartalea's method of solving cubics which want their second term, we have $x =$

$$\sqrt[3]{\sqrt{\frac{m^2}{4} - \frac{a^3}{27}} - \frac{m}{2}} + \sqrt[3]{-\sqrt{\frac{m^2}{4} - \frac{a^3}{27}} - \frac{m}{2}}$$

But in the present instance $\frac{m^2}{4} = \frac{a^3}{27}$

Whence the equations

$$\sqrt[3]{\sqrt{\frac{m^2}{4} - \frac{a^3}{27}}} \text{ and } + \sqrt[3]{-\sqrt{\frac{m^2}{4} - \frac{a^3}{27}}}$$

destroy each other; Consequently, $x = \sqrt[3]{-\frac{m}{2}} + \sqrt[3]{-\frac{m}{2}} = 2\sqrt[3]{-\frac{m}{2}} = \sqrt[3]{-\frac{8m}{2}} = \sqrt[3]{-4m} \therefore x = -\sqrt[3]{4m} = -\sqrt[3]{7{\cdot}77415716} = -1{\cdot}981 =$ one of the Roots. Now divide the given equation by $x + 1{\cdot}981$ and we have $x^2 - 1{\cdot}981\,x = -{\cdot}98109$ a quadratic; then by completing the square, and extracting the root, we obtain $x = +{\cdot}991$ and $-{\cdot}99$ which are the other two roots of the given equation, and determined without a conjecture, approximation, or using either of the methods alluded to in the question.

There appears to be nothing particular in this question, except that $\frac{m^2}{4}$ is equal to $\frac{a^3}{27}$ (when treated by Carden's rule); consequently two of the terms destroy each other, as stated above; but we have here no *new* method of solving cubic equations, nor any improvement on the *old*. Ed.

QUESTIONS FOR SOLUTION.

Quest. 51, *proposed by* Mr. J. M. Edney, *Clerkenwell.*

There is a circular building of 40 feet diameter, and 25 feet high to the ceiling, which is covered with a saloon (dome), the circular arch of which is 5 feet radius; required the whole content of the room in cubic feet.

Quest. 52, *proposed by* Mr. Whitcomb, *Cornhill.*

In a given quadrant of a circle to inscribe the greatest circle geometrically, and to give the demonstration.

Quest. 53, *proposed by* Mr. J. Taylor, *Clement's Lane, Lombard Street.*

Thomas and John put, monthly, into the saving's bank a certain sum of money each; the sum of their monthly deposits is £$3\frac{3}{10}$ sterling, and the sum of their 5th powers is £43·32933; I demand their respective deposits, John's being the greatest?

GEOMETRY.

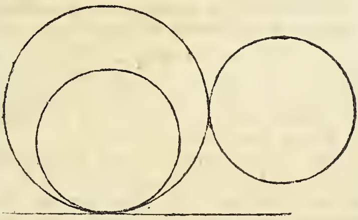
BOOK III.

DEFINITIONS.

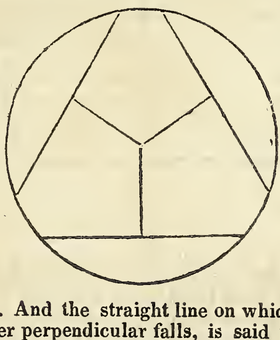
The radius of a circle is the straight line drawn from the centre to the circumference.

I. A straight line is said to touch a circle, when it meets the circle, and being produced does not cut it.

II. Circles are said to touch one another, which meet, but do not cut one another.



III. Straight lines are said to be equally distant from the centre of a circle, when the perpendiculars drawn to them from the centre are equal.

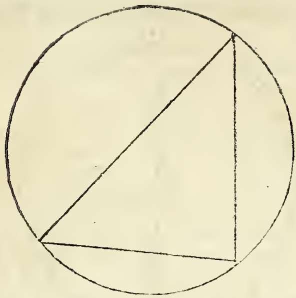


IV. And the straight line on which the greater perpendicular falls, is said to be farther from the centre.

An arch of a circle is any part of the circumference.

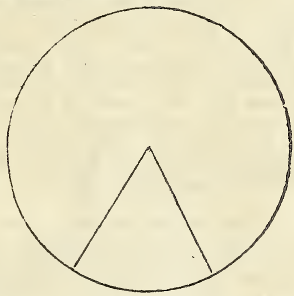
V. A segment of a circle is the figure contained by a straight line, and the arch which it cuts off.

VI. An angle in a segment is the angle contained by two straight lines drawn from any point in the circumference of the segment, to the extremities of the straight line which is the base of the segment.

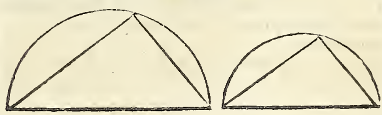


VII. And an angle is said to insist or stand upon the arch intercepted between the straight lines that contain the angle.

VIII. The sector of a circle is the figure contained by two straight lines drawn from the centre, and the arch of the circumference between them.



IX. Similar segments of a circle, are those in which the angles are equal, or which contain equal angles.



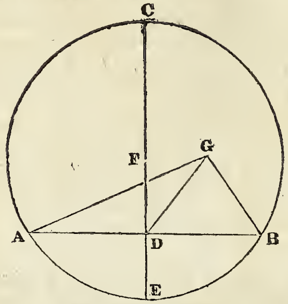
PROPOSITION I.

PROBLEM.—*To find the centre of a given circle.*

Let A B C be the given circle; it is required to find its centre.

Draw within it any straight line A B, and bisect it in D; from the point D draw D C at right angles to A B, and produce it to E, and bisect C E in F: The point F is the centre of the circle A B C.

For, if it be not, let, if possible, G be the centre, and join G A, G D, G B: Then, because D A is equal to D B, and D G common to the two triangles ADG, B D G, the two sides A D, D G are equal to the two B D, D G, each to each; and the base G A is equal to the base G B, because they are radii of the same circle: therefore the angle A D G is equal to the angle G D B: But when a straight line standing upon another straight line, makes the ad-



jacent angles equal to one another, each of the angles is a right angle. Therefore the angle G D B is a right angle: But F D B is likewise a right angle; wherefore the angle F D B is equal to the angle G D B, the greater to the less, which is impossible: Therefore G is not the centre of the circle A B C: In the same manner, it can be shown, that no other point but F is the centre; that is, F is the centre of the circle A B C: Which was to be found.

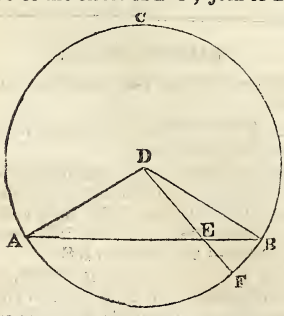
Cor. From this it is manifest, that if in a circle a straight line bisect another at right angles, the centre of the circle is in the line which bisects the other.

PROPOSITION II.

Theorem.—*If any two points be taken in the circumference of a circle, the straight line which joins them shall fall within the circle.*

Let A B C be a circle, and A B any two points in the circumference; the straight line drawn from A to B shall fall within the circle.

Take any point in A B as E; find D the centre of the circle A B C; join A D, D B



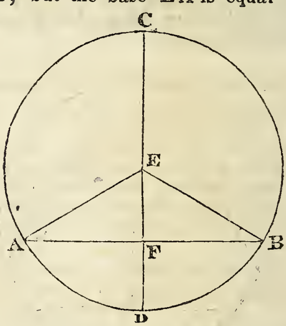
and D E, and let D E meet the circumference in F. Then because D A is equal to D B, the angle D A B is equal to the angle D B A; and because A E, a side of the triangle D A E, is produced to B, the angle D E B is greater than the angle D A E; but D A E is equal to the angle D B E; therefore the angle D E B is greater than the angle D B E: Now to the greater angle the greater side is opposite; D B is therefore greater than D E: but B D is equal to D F; wherefore D F is greater than D E, and the point E is therefore within the circle. The same may be demonstrated of any other point between A and B, therefore A B is within the circle. Wherefore, if any two points, &c. Q. E. D.

PROPOSITION III.

Theorem—*If a straight line drawn through the centre of a circle bisect a straight line in the circle, which does not pass through the centre, it will cut that line at right angles; and if it cut it at right angles, it will bisect it.*

Let A B C be a circle, and let C D, a straight line drawn through the centre, bisect any straight line A B, which does not pass through the centre, in the point F: It cuts it also at right angles.

Take E the centre of the circle, and join E A, E B. Then, because A F is equal to F B, and F E common to the two triangles A F E, B F E, there are two sides in the one equal to two sides in the other; but the base E A is equal to the



base E B; therefore the angle A F E is equal to the angle B F E. And when a straight line standing upon another makes the adjacent angles equal to one another, each of them is a right angle: Therefore each of the angles A F E, B F E is a right angle; wherefore the straight line C D, drawn through the centre, bisecting another, A B, which does not pass through the centre, cuts it at right angles.

Again, let C D cut A B at right angles; C D also bisects A B; that is, A F is equal to F B.

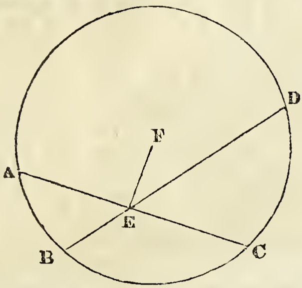
The same construction being made, because the radii E A, E B are equal to one another, the angle E A F is equal to the angle E B F; and the right angle A F E is equal to the right angle B F E: Therefore, in the two triangles E A F, E B F, there are two angles in one equal to two angles in the other; and the side E F, which is opposite to one of the equal angles in each, is common to both; therefore the other sides are equal; A F therefore is equal to F B. Wherefore, if a straight line, &c. Q. E. D.

PROPOSITION IV.

THEOREM.—*If in a circle two straight lines cut one another, which do not both pass through the centre, they do not bisect each other.*

Let A B C D be a circle, and A C, B D two straight lines in it, which cut one another in the point E, and do not both pass through the centre: A C, B D do not bisect one another.

For, if it is possible, let A E be equal to E C, and B E to E D: If one of the lines



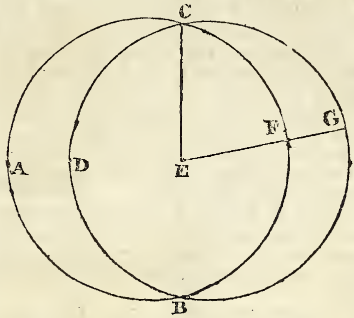
pass through the centre, it is plain that it cannot be bisected by the other, which does not pass through the centre. But if neither of them pass through the centre, take F the centre of the circle, and join E F: and because F E, a straight line through the centre, bisects another A C, which does not pass through the centre, it must cut it at right angles; wherefore F E A is a right angle. Again, because the straight line F E bisects the straight line B D, which does not pass through the centre, it must cut it at right angles; wherefore F E B is a right angle; and F E A was shown to be a right angle; therefore F E A is equal to the angle FEB, the less to the greater, which is impossible: therefore A C, B D do not bisect one another. Wherefore, if in a circle, &c. Q. E. D.

PROPOSITION V.

THEOREM.—*If two circles cut one another, they cannot have the same centre.*

Let the two circles A B C, C D G cut one another in the points B C; they have not the same centre.

For, if it be possible, let E be their centre; join E C, and draw any straight line E F G meeting them in F and G: and because E is the centre of the circle A B C, C E is equal to E F: Again, because E is



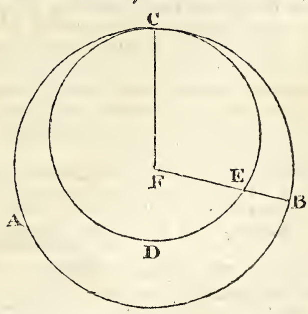
the centre of the circle C D G, C E is equal to E G: but, C E was shown to be equal to E F, therefore E F is equal to E G, the less to the greater, which is impossible: therefore E is not the centre of the circles A B C, C D G. Wherefore, if two circles, &c. Q. E. D.

PROPOSITION VI.

THEOREM.—*If two circles touch one another internally, they cannot have the same centre.*

Let the two circles A B C, C D E, touch one another internally in the point C: they have not the same centre.

For, if they have, let it be F: join F C, and draw any straight line F E B meeting them in E and B; and because F is the



centre of the circle A B C, C F is equal to F B; also, because F is the centre of the circle C D E, C F is equal to F E: but C F was shown to be equal to F B; therefore F E is equal to F B, the less to the greater, which is impossible; wherefore F is not the centre of the circles A B C, C D E. Therefore, if two circles, &c. Q. E. D.

MECHANICS.

WIND-MILLS.

Previous to concluding our observations on the subject of wind-mills, we shall add a few of the most valuable maxims deduced by Mr. Smeaton, from a number of experiments which he made to determine their greater effects.

Maxim 1. The velocity of wind-mill sails, whether unloaded or loaded, so as to produce a maximum effect, is nearly as the velocity of the wind, their shape and position being the same.

Maxim 2. The load at the maximum is nearly, but somewhat less, than as the square of the velocity of the wind, the shape and position of the sails being the same.

Maxim 3. The effects of the same sails at a maximum, are nearly, but somewhat less, than as the cubes of the velocity of the wind.

Maxim 4. The load of the same sails at the maximum, is nearly as the squares, and their effects as the cubes of their number of turns in a given time.

Maxim 5. When sails are loaded, so as to produce a maximum at a given velocity, and the velocity of the wind increases the load, continuing the same: 1st. The increase of effect, when the increase of the velocity of the wind is small, will be nearly as the squares of those velocities: 2dly, When the velocity of the wind is double, the effects will be nearly as 10 : 27½; but 3dly, When the velocities compared are more than double of that where the given load produces a maximum, the effects increase nearly in the simple ratio of the velocity of the wind.

Maxim 6. In sails where the figure and positions are similar, and the velocity of the wind the same, the number of turns in a given time, will be reciprocally as the radius or length of the sail.

Maxim 7. The load at a maximum, that sails of a similar figure and position, will overcome at a given distance from the centre of motion, will be as the cube of the radius.

Maxim 8. The effects of sails of similar figure and position, are as the square of the radius.

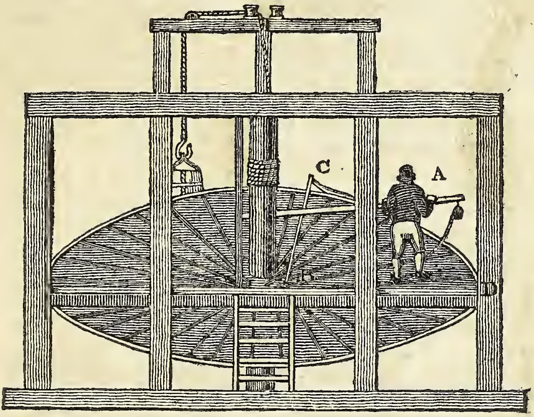
Maxim 9. The velocity of the extremities of Dutch sails, as well as of the enlarged sails in all their usual positions when unloaded, or even loaded to a maximum, are considerably quicker than the velocity of the wind.

MOTION OF MACHINES.

Machines either work with a variable or a uniform velocity. If the moving power is of the kind, that when the motion begins, diminishes in the intensity of its action, the machine, after a little time, will acquire a uniform velocity. If, however, the moving power be one that acts always with the same force, and if the resistance is also uniform, the machine will be continually accelerated. But as a motion continually accelerated, is incompatible with the purposes of machinery, it is either contrived, that by an increased resistance, the motion shall become uniform, or that the moving power shall at intervals cease altogether, or become a retarding force—so that the velocity of the machine, though continually changing, may be confined within certain limits.

When the momentum of the power applied to a machine, is greater than the momentum of the resistance, the machine is put in motion, and if the power be one that acts more forcibly on bodies at rest than in motion, its action is of course diminished, and the acceleration of the machine in the second instant, is less than in the first. This diminution of the accelerating force continues to increase, till the instant when that force becomes equal to the resistance, or till the velocity generated every instant by the one, be just equal to the velocity destroyed every instant by the other. The acceleration then ceases, and the motion of the machine becomes uniform. Now, this increase of resistance may arise in many cases from an increase of friction, which often, though not always, accompanies an augmentation of velocity; or it may arise from the resistance of the air, which must necessarily increase with the velocity; and therefore all machines are found soon to attain a state of uniform motion. When an undershot wheel is driven by the impulse of water, the uniformity of motion to which it arrives, arises principally from the diminution of the power, which in this case accompanies an increase of velocity. When the mass of fluid strikes one of the float-boards at rest, the impulse is then a maximum. When the float-board is in motion, it withdraws itself, as it were, from the action of the power, and therefore its mechanical effect will diminish as the velocity increases, and if it were possible that the velocity of the wheel should become equal to that of the fluid, the float-board would not be struck at all by the moving water. Hence it follows, that the power itself diminishes by an increase of velocity, and therefore, that from this cause alone, machines in general would soon acquire a motion sensibly uniform. This effect will be more easily understood, if we suppose an axle to be put in motion by two currents of water, moving with different velocities, and driving two wheels, one of which is placed at each extremity of the axles. When the wheels have begun to move, by the joint action of these falls of water, its motion will at first be slow, and each fall of water will perform its part in giving motion to the axle; but if the greater fall is capable, by the continuance of its action, of giving its wheel a velocity either to a greater, than the velocity of the smaller fall, then it is manifest that the smaller fall ceases to impel its wheel, and that the whole effect is produced by the action of the greater fall. Hence it is easy to understand from this statement, not only why a diminution of the impelling power accompanies an increase of velocity; but why there is a certain velocity of the machine, which is necessary before we can gain all the useful effect which we wish to have from the powers which we employ.

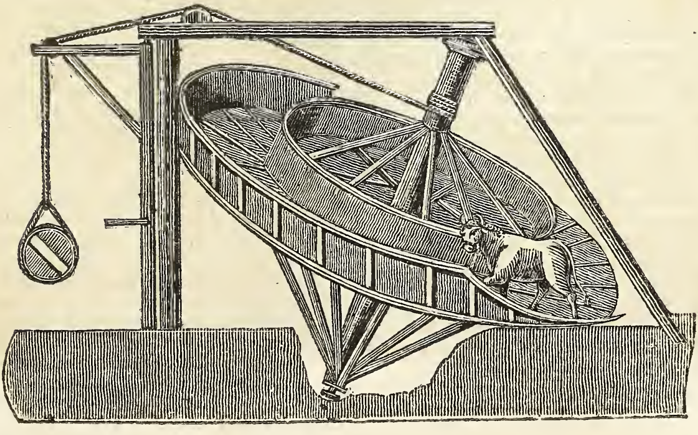
In order to illustrate this in the case of a real machine, let us suppose that the power of a man is to be employed in raising a load, by means of the machine or walking crane exhibited by the following figure.



Here the man walks at any required distance from the axis of motion, and pushes forward the lever A, which moves the bar BC, connected with the same axis, and removes the break C D from the circumference of the wheel.

From an attentive consideration of this machine, it will soon be perceived, that as the acceleration increases, the man must walk with greater and greater velocity; but there is an obvious limit to this, for he would soon be fatigued by the rapid walking, and therefore be rendered unfit to continue his work. He must therefore return to that distance from the axis, where the wheel has such a velocity, as he can continue to move with during the period that his work is to last, there is therefore a particular velocity with which the man must walk, in order to perform the greatest quantity of work; and it would be easy to find this velocity, if we knew the law according to which his force diminished as his velocity increased. We may suppose, however, that his force *diminishes* in the same ratio as his velocity *increases*.

But previous to considering this more particularly, we shall give a representation of an oblique *walking wheel*, for oxen or horses.



We may, however, remark, that it is advisable that walking wheels for quadrupeds should present to them a path as little elevated as possible; and it might probably be advantageous to harness them, either to a fixed point, or to a spring or weight, which would enable them to exert a considerable force, even in a horizontal direction; but probably after all, they might be more advantageously employed in a circular mill walk.

In all machines the work done is to be estimated, not merely from the quantity of resistance overcome, but from the quantity overcome in a given time; or, which is the same, from the quantity of the resistance multiplied into the velocity communicated.

The resistance is here supposed to be expressed by weight, and the effect by that weight multiplied into the velocity with which it is raised.

In all machines that work with a uniform motion, there is a certain velocity and a certain load, that yield the greatest effect, and which are therefore more advantageous than any other.

If the machine is loaded heavily, though the resistance overcome may be great, it may be overcome so slowly, that the total effect shall be but small. And, again, if the machine is loaded very lightly, it will give great velocity to the load, though, from the smallness of its quantity, the effect will still be inconsiderable. Between these two loads, there must be some intermediate one, that will make the effect the greatest possible.

If the moving power observe the same law that has been already ascribed to animal force, (see pages 276 and 277), then the effect of the machine will be the greatest possible, when the load is reduced to *four-ninths* of the load or resistance, which is just able to keep the machine at rest, or prevent its motion altogether.

The moving power and the resistance being both given, other things remaining as above, if a machine be so constructed, that the velocity of the point to which the power is applied, be to the velocity of the point to which the resistance is applied, as 9 times the resistance to 4 times the power, the machine will work to the greatest possible advantage.

Under the name of the load, we suppose the friction of the parts of the machine to be comprehended, which must therefore be determined by experiment.

Care should be taken to give to every machine the greatest possible regularity in its motion.

The contrivance known by the name of a fly, is one of the best adapted for this purpose. When the impelling power is subject to alternate intention and remission, the inertia of a heavy wheel, by preserving the velocity it has acquired, tends to lessen the irregularity resulting from these causes.

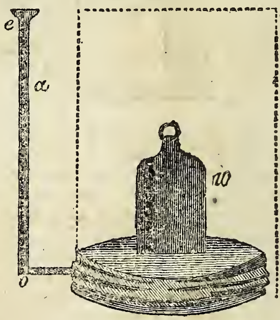
The effect of a fly to remove irregularity in the motion of a machine, its weight and diameter being given, is proportional to its velocity.

HYDRAULICS.

HYDROSTATIC BELLOWS.

The Hydrostatic bellows being a machine much used in large founderies, for producing a constant and equal blast of air, we shall give a short description of it, and endeavour to explain the principle upon which it acts.

This machine is made of two strong round boards united by strong leather, in the manner of common bellows, but nailed so tight to the edges of the boards as to hold water. It is represented by the following figure.

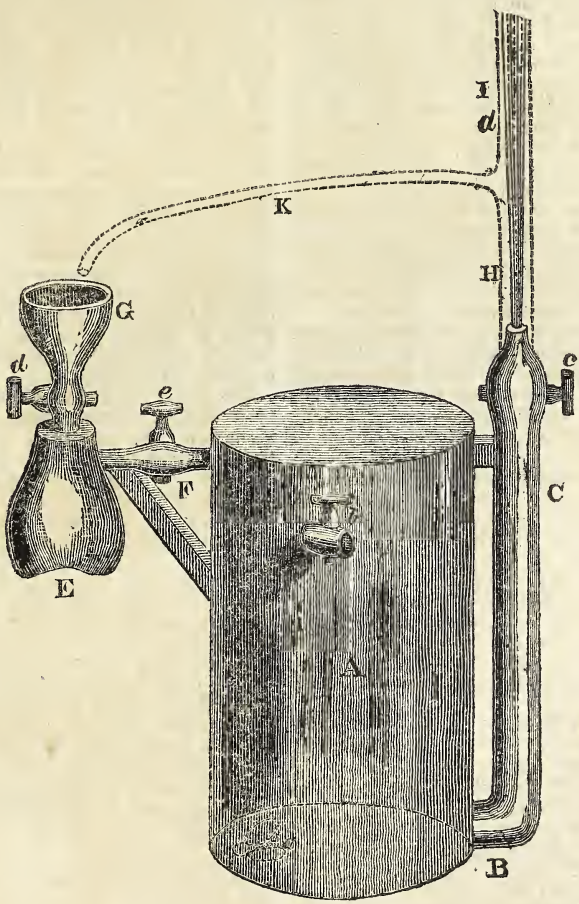


Here *a* is a pipe of any height leading into the inside of the bellows. If water be poured into this pipe, the upper board will soon begin to rise and lift the weight *w*; and if the pipe was tall, and that board wide enough, it would lift the man who poured in the water. If, when the bellows are full of water, weights are laid on them till the water was forced up to the top of the pipe *a*, those weights would express the weight of a pillar of water, whose base was equal to the area of the under-board of the bellows, and whose height was from that board to the top of the pipe *a*; which may be better understood by the dotted line in the figure. It is evident, that the returning pillar *n a* would press as forcibly against the bottom *n* by re-action, as the tall pillar *b n* by its weight, for the pressure against the thumb *a* was equal to the weight of water between *b* and *c*, and therefore the re-action of the short pillar upon *n*, would be equal to the weight of the tall pillar. This reasoning applied to the bellows, will account for the weight they lift; for the water within the bellows is all returning pillars, (like *n a* when the pipe *a* is full), each endeavouring to raise to the level *e n*, and thrusting against the lid, with a force that would bring them to that level, if they had an opportunity. But if, instead of the pillar of water *e o*, acting on the bellows by its weight, that water was *forced* in by a piston moving in *e o*, the bellows, if strong enough, would lift a ship or a house!

It is on this principle that the pressure of water has been applied by Mr. Bramah, to the construction of a very convenient press, which will be described in another part of this work.

BLAKEY'S MACHINE FOR RAISING WATER FROM MINES, RIVERS, &c.

This machine is represented by the following figure.



A is a large, strong, close vessel, immersed in water up to the cock *b*, and having a hole in the bottom, with a valve *a* upon it, opening upward within the vessel. B C is a pipe which rises from the bottom of the vessel, and has a cock *c* in it near the top, which is there very small, for raising a jet *d* to a great height. E is a little boiler (not so large as a common tea kettle) which is connected with the vessel A by the steam pipe E; and G is a funnel, through which a little water must be occasionally poured into the boiler, to yield a proper quantity of steam. And a small quantity of water will do for that purpose, because steam occupies upwards of 14,000 times as much space or bulk, as the water does from which it proceeds.

The vessel A being immersed in water up to the cock *b*, open that cock, and the water will rush in, through the bottom of the vessel at *a*, and fill it as high up as the water stands on its outside; and the water, coming into the vessel, will drive the air out of it (as high as the water rises within it) through the cock *b*. When the water has done rushing into the vessel, shut the cock *b*, and the valve *a* will fall down, and hinder the water from being pushed out that way, by any force that presseth on its surface. All the part of the vessel above *b*, will be full of common air, when the water rises to *b*.

To set the machine to work, it is only necessary to shut the cock *c*, and open the cocks *d* and *e;* then pour as much water into the boiler E (through the funnel G) as will half fill the boiler; and then shut the cock *d*, and leave the cock *e* open.

This being done, a fire is to be made under the boiler E, the heat of which will raise steam from the water in the boiler, which will make its way through the pipe F, into the vessel A; and the steam will compress the air above *b* with a very great force upon the surface of the water in A.

When the top of the vessel A feels very hot by the steam under it, open the cock *c* in the pipe C; and the air being strongly compressed in A, between the steam and the water in it, will drive all the water out of the vessel A, up the pipe B C, from which it will fly up in a jet to a very great height. Mr. Ferguson says, "that he made a machine of this kind, which, with three tea-cups full of water in the boiler, afforded steam enough to raise a jet 30 feet high."

When all the water is out of the vessel A, and the compressed air begins to follow the jet, open the cocks *b* and *d* to let the steam out of the boiler E and vessel A, and shut the cock *e* to prevent any more steam from getting into A; and the air will rush into the vessel A through the cock *b*, and the water through the valve *a;* and so the vessel will be filled up with water to the cock *b* as before. Then shut the cock *b*, and the cocks *c* and *d*, and open the cock *e;* and then, the next quantity of steam that rises in the boiler, will make its way into the vessel A again; and the operation will go on as above.

When all the water in the boiler E is evaporated, and gone off into steam, pour a little more into the boiler, through the funnel G.

In order to make this engine raise water to supply a house, which is situated on the bank of a river, the pipe B C may be continued up to the intended height, in the direction H I. Or, if the house be on the side or top of a hill, at a distance from the river, the pipe, through which the water is forced up, may be laid along on the hill, from the river or spring to the house.

The boiler may be fed by a small pipe K, from the water that rises in the main pipe B C H I; the pipe K being of a very small bore, so as to fill the funnel G with water, in the time that the boiler E will require a fresh supply. And then, by turning the cock *d*, the water will fall from the funnel into the boiler. The funnel should hold as much water as will about half fill the boiler.

When either of these methods of raising water perpendicularly or obliquely, is used, there will be no occasion for having the cock *c* in the main pipe B C H I: for such a cock is requisite only, when the engine is used as a fountain.

A contrivance may be very easily made, from a lever to the cocks *b*, *d*, and *e;* so that, by pulling the lever, the cocks *b* and *d* may be opened, when the cock *e* must be shut; and the cock *e* be opened, when *b* and *d* must be shut.

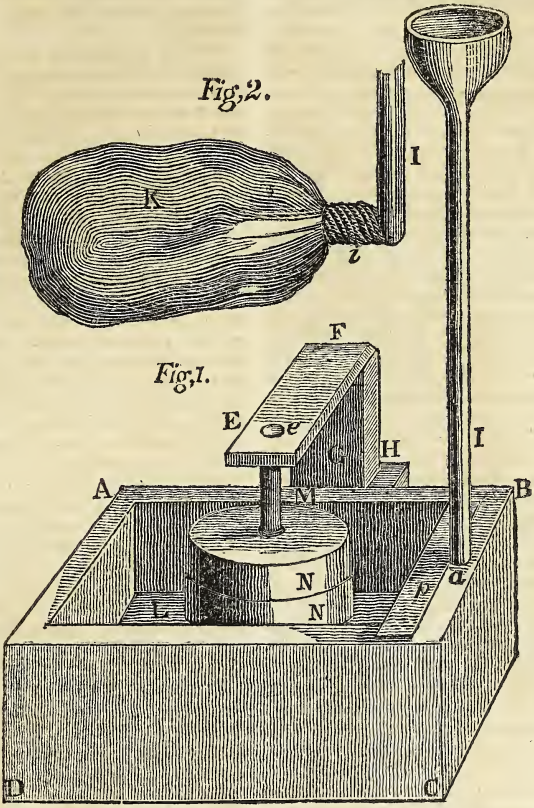
The boiler E should be inclosed in a brick wall, at a little distance from it, all around, to give liberty for the flames of the fire under the boiler to ascend round about it. By which means, (the wall not covering the funnel G) the force of the steam will be prodigiously increased by the heat round the boiler; and the funnel and water in it will be heated from the boiler; so that the boiler will not be chilled by letting cold water into it; and the rising of the steam will be so much the quicker.

This engine may be constructed at a trifling expense, in comparison of the common steam engines now in use: it will seldom need repairs, and will not consume half so much fuel. And as it has no pumps with pistons, it is clear of all their friction: and the effect is equal to the whole strength or compressive force of the steam.

A MACHINE TO BE SUBSTITUTED FOR THE HYDROSTATIC BELLOWS.

This machine is represented by the following figure.

Fig, 2.



Fig, 1.

ABCD (fig. 1st.) is an oblong square box, in one end of which is a round groove, as at *a*, from top to bottom, for receiving the upright glass tube I, which is bent to a right angle at the lower end (as at *i* in fig. 2,) and to that part is tied the end of a large bladder K, (fig. 2) which lies in the bottom of the box. Over this bladder is laid the moveable board L, in which is fixed an upright wire M; and leaden weights N N, to the amount of 16 pounds, with holes in their middle, are put upon the wire, over the board, and press upon it with all their force.

The cross bar *p* is then put on, to secure the tube from falling, and keep it in an upright position: And then the piece EFG is to be put on, the part G sliding tight into the dove-tailed groove H, to keep the weights N N horizontal, and the wire M upright; there being a round hole *e* in the part E F for receiving the wire.

There are four upright pins in the four corners of the box within, each almost an inch long, for the board L to rest upon; to keep it from pressing the sides of the bladder below it, close together at first.

The whole machine being thus put together, pour water into the tube at top, and the water will run down the tube into the bladder below the board; and after the bladder has been filled up to the board, continue pouring water into the tube, and the upward pressure which it will excite in the bladder, will raise the board with all the weight upon it, even though the bore of the tube should be so small, that less than an ounce of water would fill it.

This machine acts upon the same principle as the *Hydrostatical* paradox (see page 9.) For the upward pressure against every part of the board (which the bladder touches) equal in area to the area of the bore of the tube, will be pressed upward with a force equal to the weight of the water in the tube; and the sum of all these pressures, against so many areas of the board, will be sufficient to raise it with all the weights upon it.

This simple machine is well calculated for showing the upward pressure of fluids.

Miscellaneous Subjects.

MEMOIR OF DR. FRANKLIN.

(Continued from page 358.)

He afterwards demonstrated by experiments, that the electricity did not reside in the coating, as had been supposed, but in the pores of the glass itself. After a phial was charged, he removed the coating, and found that upon applying a new coating, the shock might still be received. In 1749, he first suggested the idea of explaining the phenomena of thunder-gusts, and of the aurora borealis, upon electrical principles. He points out many particulars, in which lightning and electricity agree; and he adduces many facts, and reasonings from facts, in support of his positions. In the same year he conceived the bold and grand idea of ascertaining the truth of his doctrine, by actually drawing down the forked lightning, by means of sharp pointed iron rods raised into the region of the clouds; from whence he derived his method of securing buildings and ships from being damaged by lightning. It was not until the summer of 1752, that he was enabled to complete his grand discovery, the experiment of the electrical kite, which being raised up into the clouds, brought thence the electricity or lightning down to the earth; and M. D'Alibard made the experiment about the same time in France, by following the track which Franklin had before pointed out. The letters which he sent to Mr. Collinson, it is said, were refused a place among the papers of the Royal Society of London; and Mr. Collinson published them in a separate volume, under the title of "New Experiments and Observations on Electricity, made at Philadelphia, in America," which were read with avidity, and soon translated into different languages. His theories were at first opposed by several philosophers, and by the members of the Royal Society of London; but in 1755, when he returned to that city, they voted him the gold medal, which is annually given to the person who presents the best paper on some interesting subject. He was also admitted a member of the Society, and had the degree of LL.D. conferred upon him by different Universities; but at this time, by reason of the war which broke out between Britain and France, he returned to America, and interested himself in the public affairs of that country. Indeed, he had done this long before; for although philosophy was a principal object of Franklin's pursuit for several years, he did not confine himself to it alone. In 1747, he became a member of the general assembly of Pennsylvania, as a burgess for the city of Philadelphia. Being a friend to the rights of man from his infancy, he soon distinguished himself as a steady opponent of the unjust schemes of the proprietaries. He was soon looked up to as the head of the opposition; and to him have been attributed many of the spirited replies of the assembly to the messages of the governors. His influence in the body was very great, not from any superior powers of eloquence; he spoke but seldom, and he never was known to make any thing like an elaborate harangue; but his speeches generally consisting of a single sentence, or of a well-told story, the moral was always obviously to the point. He never attempted the flowery fields of oratory. His manner was plain and mild. His style in speaking was, like that of his writings, simple, unadorned, and remarkably concise. With this plain manner, and his penetrating and solid judgment, he was able to confound the most eloquent and subtle of his adversaries, to confirm the opinions of his friends, and to make converts of the unprejudiced who had opposed him. With a single observation he has rendered of no avail a long and elegant discourse, and determined the fate of a question of importance.

In 1749 he proposed a plan of an academy to be erected in the city of Philadelphia, as a foundation for posterity to erect a seminary of learning, more extensive and suitable to future circumstances; and in the beginning of 1750, three of the schools were opened; namely, the Latin and Greek school, the mathematical and the English schools. This foundation soon after gave rise to another more extensive college, incorporated by charter, May 27, 1755, which still subsists, and in a very flourishing condition. In 1752 he was instrumental in the establishment of the Pennsylvania hospital, for the cure and relief of indigent invalids, which has proved of the greatest use to that class of persons. Having conducted himself so well as post-master of Philadelphia, he was in 1753, appointed deputy post-master general for the whole British colonies.

After the defeat of General Braddock, in 1755, Franklin introduced into the assembly a bill for organizing a militia, and had the dexterity to get it passed. In consequence of this act, a very respectable militia was formed; and Franklin was appointed colonel of a regiment in Philadelphia, which consisted of 1200 men; and in which capacity he acquitted himself with much propriety, and was of singular service, though this militia was soon after disbanded by order of the English ministry.

In 1757 he was sent to England, with a petition to the king and council, against the proprietaries, who refused to bear any share in the public expenses and assessments, which he got settled to the satisfaction of the state. After the completion of this business, Franklin remained at the court of Great Britain for some time, as agent for the province of Pennsylvania; and also for those of Massachusetts, Maryland, and Georgia. Whilst here, he invented the elegant musical instrument called the Harmonica, formed of glasses played on by the fingers. In the summer of 1762 he returned to America, on the passage to which he observed the singular effect produced by the agitation of a vessel containing oil, floating on water; the upper surface of the oil remained smooth and undisturbed, whilst the water was agitated with the utmost commotion. On his return he received the thanks of the assembly of Pensylvania; which having annually elected him a member in his absence, he again took his seat in this body, and continued a steady defender of the liberties of the people. In 1764, by the intrigues of the proprietaries, Franklin lost his seat in the assembly, but was immediately appointed provincial agent to England. In 1766 he was examined before the Parliament relative to the stamp act, which was soon after repealed. The same year he made a journey into Holland and Germany, and another into France, being every where received with the greatest respect by the literati of all nations. On the 29th January, 1774, he was examined before the Privy Council, on a petition which he had presented long before as agent for Massachusetts Bay against Mr. Hutchinson: but this petition being disagreeable to ministry, it was precipitately rejected, and he was soon after removed from his office of postmaster-general for America Finding now all efforts to restore harmony between Great Britain and her Colonies useless, he returned to America in 1775, just after the commencement of hostilities. Being named one of the delegates to the Continental Congress, he had a principal share in bringing about the revolution and declaration of independency on the part of the Colonies. When it was determined by Congress to open a public negotiation with France, Dr. Franklin was fixed upon to go to that country; and he brought about the treaty of alliance offensive and defensive, which produced an immediate war between England and France.

Dr. Franklin was one of the Commissioners, who, on the part of the United States, signed the provisional articles of peace in 1782, and the definitive treaty in the following year. Before he left Europe, he concluded a treaty with Sweden and Prussia. Having seen the accomplishment of his wishes in the independence of his country, he requested to be recalled, and after repeated solicitations, Mr. Jefferson was appointed in his stead On the arrival of his successor, he repaired to Havre de Grace, and crossing the English channel, landed at Newport, in the Isle of Wight, from whence, after a favourable passage, he arrived safe at Philadelphia, in September, 1785. Here he was received amidst the acclamations of a vast and almost innumerable multitude, who had flocked from all parts to see him, and who conducted him in triumph to his own house, where in a few days he was visited by the members of congress, and the principal inhabitants of Philadelphia. He was afterwards twice chosen president of the assembly of Philadelphia; but in 1788, the increasing infirmities of his age obliged him to ask and obtain permission to retire, and spend the remainder of his life in tranquillity; and on the 17th of April, 1790, he died at the great age of eighty-four years and three months. He left behind him one son, and a daughter married to a merchant in Philadelphia.

Dr. Franklin was author of many tracts on electricity, and other branches of natural philosophy, as well as on political and miscellaneous subjects. Many of his papers are inserted in the Philosophical Transactions of London: and his essays have been frequently reprinted in this country as well as in America, and have, in common with his other works, been translated into several modern languages. A complete edition of all these was printed in London in 1806, in 3 vols. 8vo. with "Memoirs of his early Life," written by himself, to which the preceding article is in a considerable degree indebted.

As a philosopher, the distinguishing characteristics of Franklin's mind, as they have been appreciated by a very judicious writer, seem to have been a clearness of apprehension, and a steady undeviating common sense. We do not find him taking unrestrained excursions into the more difficult labyrinths of philosophical inquiry, or indulging in conjecture and hypothesis. He is in the constant habit of referring to acknowledged facts and observations, and suggests the trials by which his speculative opinions may be put to the test. He does not seek for extraordinary occasions of trying his philosophical acumen, nor sits down with the preconceived intention of constructing a philosophical system. It is in the course of his familiar correspondence that he proposes his new explanations of phenomena, and brings into notice his new discoveries. If a mere hypothesis be proposed, the author himself is the first to point its insufficiency, and abandons it with more facility than he had constructed it. Even the letters on electricity, which are by far the most finished of Franklin's performances, are distinctly characterized by all these peculiarities. The Doctor never betrays any exertion, nor displays an unwarrantable partiality for his own speculations; he assumes no superiority over his readers, nor seeks to elevate the importance of his conceptions, by the adventitious aid of declamation, or rhetorical flourishes. He exhibits no false zeal, no enthusiasm, but calmly and modestly seeks after truth; and if he fails to find it, has no desire to impose a counterfeit in its stead.

DESCRIPTION OF GUNTER'S. SCALE.

(Continued from page 349.)

Having described the lines drawn upon one side of this useful instrument at page 347, we shall here describe those upon the other side, in order to render our description complete.

For the sake of distinction, we called the lines on the one side *natural* lines, and those on the other *artificial*, or logarithmic lines; the latter only remain to be noticed, and are the following:

	Marked.
Sine Rhumbs - - -	S. R.
Tangent Rhumbs - -	T. R.
Numbers - - -	NUM.
Sines - - - - -	SIN.
Versed Sines - - -	V. S.
Tangents - - -	TAN.
Meridional Parts - -	MER.
Equal Parts - - - -	E. P.

1. *The Line of Numbers*—We begin with the construction of this logarithmic line, because all the other lines are constructed with reference to it. The purposes to which this line is usually applied do not require that it should have numbers represented on it, such that the greatest should exceed the least more than 100 times; and accordingly as the common logarithm of 100 is 2, and that of 10 is 1, the line of numbers is made to consist of two equal parts, the subordinate divisions in one of which have a reference to an order of units, ten times greater than those of the other. Let an accurate scale of equal parts, therefore, be constructed of half the length of the proposed line of numbers, and for the sake of greater precision let it be a diagonal scale, with ten primary divisions. Then, from this scale take the measure of the logarithm of 2, and lay it off from the beginning of the scale; in like manner take the length of the logarithms of 3, 4, 5, &c. from the scale of equal parts, and lay them off from the *beginning;* lay off also the intermediate divisions, and the first half of the scale will be constructed. The other half is constructed exactly in the same manner.

It is scarcely necessary to observe, that if the first unit, at the beginning of the scale, be reckoned 1, the second unit is 10, and the third 100; whereas, if the first unit be accounted 10, the send is 100, and the third 1000; and so on with regard to any other value that may be attached to the first unit.

2. *The Line of Sine Rhumbs.*—From the same scale of equal parts which was employed in the construction of the line of numbers, take the distances expressed by the three first figures of the arithmetical complement,* of the logarithmic sines of 7, 6, 5, points, &c. or the secants of 1, 2, 3, points, &c. rejecting the indices, and lay them off, towards the left hand successively from the point corresponding to the sine of 90°, which is usually placed immediately below the last unit on the right hand of the line of numbers; and thus the scale of rhumbs will be obtained for the several points. The quarter points are laid down after the same manner.

3. *The Line of Sines.*—The construction of the scale of logarithmic sines differs in no respect from that of the rhumbs, only degrees are employed in place of points.

4. *The Line of Tangent Rhumbs.*—This scale, as far as 4 points, is constructed in the same manner as the scale of log. sines, by using the three first figures of arithmetical complements of the logarithmic tangents of 3, 2, and 1 points, or of the logarithms of the tangents of 5, 6, and 7 points, rejecting the index. The tangent of 4 points being equal to the radius, terminates the scale on the right hand. The points above 4, if the scale were extended from that point towards the right hand, would be at the same distance from 4, or the point corresponding to the radius, as the points as much below 4 are from that point. Hence the points corresponding to 3 and 5 points, 2 and 6 points, and 1 and 7 points, are coincident on the scale, only the points above 4, though actually laid down to the left hand of the point corresponding to the

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* The arithmetical complement of the sine, tangent, &c. of an arc, is the remainder obtained by subtracting it from 10·000000.

radius, must be conceived, in the performance of problems, to extend to the right hand of it.

5. *The Line of Tangents.*—The scale of logarithmic tangents is constructed, like that of logarithmic tangent rhumbs, by employing the three first figures of the arithmetical complements of the log. tangents of 40°, 30°, &c. or of the logarithms of the tangents of 50°, 60°, rejecting their indices.

6. *The Line of Versed Sines.*—From the scale of equal parts, employed in the construction of all the preceding scales, take the distances expressed by the three first figures of the arithmetical complements of the logarithmic cosines of 5, 10, 15, &c. degrees, rejecting the indices, and lay off the double of these distances, respectively, from right to left of the extended scale. The divisions, thus obtained, will correspond to the log. versed sines of 10, 20, 30, &c. degrees.

7. *Meridional Line.*—Take the meridional parts for every 10° from a Table of meridional parts, and having divided them by 60, lay off, by means of some convenient scale of equal parts, the distance expressed by the several quotients. The line of equal parts, which is placed immediately above or below the meridional line, is divided into 19 principal divisions, marked from right to left 0, 10, 20, &c. each of these divisions representing 10 degrees of the equator, or 600 nautical miles. The first division on the right from 0 to 10, is divided into 10 equal parts, each of which, therefore, corresponds to a degree of the equator, or 60 miles; and, consequently, the bisection of each of these equal parts reduces the ultimate divisions to a distance representing 30 miles. The extent from the right hand extremity of the meridional line to any particular division, being applied, in like manner, to the scale of equal parts, will indicate in degrees the meridional parts belonging to that division, reckoned from the equator. Also the extent between any two divisions in the meridional line being applied to the line of equal parts, will give, in degrees, the meridional difference of latitude between the two latitudes, expressed by the numbers at the extreme points of extent. Hence the compound scale may serve, instrumentally, the purposes of a table of meridional parts.

In using these logarithmic scales for the solution of arithmetical problems, in trigonometry or navigation, it follows from the nature of logarithms, that the fourth term of four proportional magnitudes being to the third, as the second to the first, if these magnitudes be A, B, C, and D, then A divided by B, is equal to C, divided by D; and, consequently, the logarithm of A, diminished by the logarithm of B, is equal to the logarithm of C, diminished by the logarithm of D. That is, the extent from the log. A to the log. B, these two quantities being of the same kind, will reach from the log. C to the log D, always carefully observing that the extent in the second case must be taken in the same direction as in the first. This circumstance, which must never be lost sight of, requires to be particularly observed in solving problems where the scale of logarithmic tangents is employed, and the third term is the tangent of 45° on the radius. In such cases, when the extent is from the left to the right, in respect of the two first terms, the extent ought to be taken in the same direction on the scale of tangents; but the manner of laying down the scale not admitting this, the extent is taken from right to left, only the complement of the number of degrees and minutes corresponding to it is taken, in place of the numbers actually marked on the scale. A similar precaution is to be observed when either the first or second term of an analogy is greater than 45°, the extent in the second case being always reckoned in the same direction of what it would have been, if the line of logarithmic tangents had been continued to the right hand of 45°.

UNIFORMITY OF WEIGHTS AND MEASURES.

A Bill having passed in the last session of Parliament, for establishing a uniformity of weights and measures throughout the country, we consider that we shall render a service to our readers, by making them acquainted with the most important parts of it. This we conceive will be best accomplished by making a few extracts from the Act itself.

"I. That from and after the first day of May, one thousand eight hundred and twenty-five, the straight line or distance between the centres of the two points in the gold studs in the straight brass rod, now in the custody of the clerk of the House of Commons, whereon the words and figures 'Standard Yard, 1760,' are engraved, shall be and the same is hereby declared to be the original and genuine standard of that measure of length or lineal extension called a yard; and that the same straight line or distance between the centres of the said two points in the said gold studs in the said brass rod, the brass being at the temperature of sixty-two degrees by *Fahrenheit's* Thermometer, shall be and is hereby denominated the 'Imperial Standard Yard,' and shall be and is hereby declared to be the unit or only standard measure of extension, wherefrom or whereby all other measures of extension whatsoever, whether the same be lineal, superficial, or solid, shall be derived, computed, and ascertained; and that all measures of length shall be taken in parts or multiples, or certain proportions of the said standard yard; and that one-third part of the said standard yard shall be a foot, and the twelfth part of such foot shall be an inch; and that the pole or perch in length shall contain five such yards and a half, the furlong two hundred and twenty such yards, and the mile one thousand seven hundred and sixty such yards.

"II. And be it further enacted, That all superficial measure shall be computed and ascertained by the said standard yard, or by certain parts, multiples, or proportions thereof; and that the Rood of land shall contain one thousand two hundred and ten square yards, according to the said standard yard; and that the Acre of land shall contain four thousand eight hundred and forty such square yards, being one hundred and sixty square Perches, Poles, or Rods.

"III. And whereas it is expedient that the said standard yard, if lost, destroyed, defaced, or otherwise injured, shall be restored of the same length, by reference to some invariable natural standard: And whereas it has been ascertained by the commissioners appointed by His Majesty to inquire into the subject of weights and measures, that the said yard hereby declared to be the imperial standard yard, when compared with a Pendulum vibrating seconds of mean time, in the latitude of *London*, in a vacuum at the level of the sea, is in the proportion of thirty-six inches to thirty-nine inches, and one thousand three hundred and ninety-three ten-thousandth parts of an inch; be it therefore enacted and declared, That if at any time hereafter the said imperial standard yard shall be lost, or shall be in any manner destroyed, defaced, or otherwise injured, it shall and may be restored by making, under the direction of the Lord High Treasurer, or the Commissioners of His Majesty's Treasury of the United Kingdom of *Great Britain* and *Ireland*, or any three of them, for the time being, a new standard yard, bearing the same proportion to such pendulum as aforesaid, as the said imperial standard yard bears to such pendulum.

"IV. And be it further enacted, That from and after the first day of *May*, one thousand eight hundred and twenty-five, the standard brass weight of one Pound Troy weight, made in the year one thousand seven hundred and fifty-eight, now in the custody of the Clerk of the House of Commons, shall be and the same is hereby declared to be the original and genuine standard measure of weight, and that such brass weight shall be and is hereby denominated the imperial standard Troy pound, and shall be and the same is hereby declared to be the unit or only standard measure of weight, from which all other weights shall be derived, computed, and ascertained; and that one-twelfth part of the said troy pound shall be an ounce; and that one-twentieth part of such ounce shall be a penny-weight; and that one-twenty-fourth part of such pennyweight shall be a grain; so that five thousand seven hundred and sixty such grains shall be a troy pound, and that seven thousand such grains shall be and they are hereby declared to be a pound avoirdupoise, and that one-sixteenth part of the said pound avoirdupois shall be an ounce avoirdupois, and that one-sixteenth part of such ounce shall be a dram.

"V. And whereas it is expedient, that the said standard troy pound, if lost, destroyed, defaced, or otherwise injured, should be restored of the same weight, by reference to some invariable natural standard: And whereas it has been ascertained, by the Commissioners appointed by His Majesty to inquire into the subjects of weights and measures, that a cubic inch of distilled Water, weighed in air by brass weights, at the temperature of sixty-two degrees of *Fahrenheit's* thermometer, the barometer being at thirty inches, is equal to two hundred and fifty-two grains, and four hundred and fifty-eight thousandth parts of a grain, of which, as aforesaid, the imperial standard troy pound contains five thousand seven hundred and sixty; be it therefore enacted, That if at any time hereafter the said imperial standard troy pound shall be lost, or shall be in any manner destroyed, defaced, or otherwise injured, it shall and may be restored by making, under the directions of the Lord High Treasurer, or the Commissioners of His Majesty's Treasury of the United Kingdom of *Great Britain* and *Ireland*, or any three of them for the time being, a new standard troy pound, bearing the same proportion to the weight of a cubic inch of distilled water, as the said standard pound hereby established bears to such cubic inch of water.

(*To be continued.*)

To the Editor of the Artisan.

SIR,

In Nicholson's Philosophical Journal for June 1803, I met with a letter from M. Van Marum to M. Bertholet, containing an account of some experiments, shewing the method of extinguishing violent fires with very small quantities of water, *by means of portable pumps;* and as this method appears to me, from its simplicity, capable of being made extremely useful, not only in crowded cities, but on board ships, I request you will have the goodness to give it a more general circulation, by inserting the following brief account of it in the Artisan.

The Experiments of Van Aken, a Swede, which were published in 1794, and which gave rise to Van Marum's, were performed with a liquid of the following composition; *viz.* 40 lbs. of sulphate of iron, and 30 lbs. of sulphate of allumine, mixed with 20 lbs. of the red oxide of iron and 200 lbs. of clay. By a series of experiments Van Marum proved, that fire was always extinguished more quickly by *common water*, used in the same manner, than by this anti-incendiary liquor; and, "I observed," he says, "at the same time, that a very inconsiderable quantity of water, if judiciously directed, would extinguish a very violent fire." The result of his first experiment, was the extinguishing the fires of two casks covered with pitch, their heads taken out, and highly ignited, *with only four ounces of water.* I shall give his instructions at length as follow:—"According to these experiments it appears, that the art of extinguishing a violent fire with a small quantity of water, consists in this, that the water be thrown on that part of the fire which is most violent, so that the quantity of steam produced, which suppresses the flame, may be the greatest possible; that water be continued to be thrown on the neighbouring inflamed parts as soon as the fire has ceased in that on which the operation was began, and that all the burning parts be visited in this way as quickly as possible. By thus following the flames regularly with streams of water they may be every where suppressed, before the part on which the operation was began shall have entirely lost by evaporation the water with which it was extinguished: this is often necessary to prevent the parts from breaking out a-fresh; for, in the principle above-mentioned, a burning body of which the flames are suppressed, cannot be again in flames until the water thrown on it be totally extinguished.

In May, 1797, Van Marum prepared a shell of dry wood, forming a room 24 feet long, 23 feet wide, and 14 feet high, having two doors on one side and two windows on the other; the inside was strongly pitched, and covered with twisted straw, wood shavings, and cotton, soaked in turpentine. "Very soon after lighting it," he says, "the flames being rendered more brisk by the wind, were every where so violent, that it was considered by my assistants as impossible to extinguish them. I succeeded, however, after the method above directed, in little more than four minutes, and with five buckets of water, a part of which was wasted by the negligence of my Assistant. This experiment was repeated in the same month, and the fire extinguished in 3 minutes, with less than 5 gallons of water. A similar experiment was repeated with equal success by Dr. Van Marum, in the presence of the Duke and Duchess of Gotha, at Gotha, in July, 1798; an account of which was published by the celebrated Astronomer Von Zach, in a German periodical paper, entitled *Reich's Anrioger*, 6th April, 1798, No. 119,—where he assures us that *the fire was extinguished with* 3 *buckets of water, in* 3 *minutes, with a small portable pump.*

Van Marum concludes with the following observations. "In operations of this kind, particular attention must be paid to throwing the water in such a way, that the entire surface of the burning parts shall be wetted and extinguished, and that in such a way, that an extinguished part shall never be left between two others which are in flames; for if attention be not paid to this, the heat of the flames burning here and there, will quickly change the water with which the part has been wetted into steam, and the whole will again take fire. In order then to extinguish a fire in all cases, no more water must be thrown on the burning part than is needful to wet the surface; and this I conceive to be all that is requisite to extinguish a fire, whatever may be the circumstances of its origin."

In 1807, Mr. Hornblower, with whose talents the world is so well acquainted, constructed a fire engine which stood in the compass of 14 inches square, and 2 feet high, and could be carried from one room to another with ease—he found by experiments, that the 4 sides of a bedroom all on fire, could be extinguished in the space of a minute, by little more than a pail of water. All that is required, is to keep the engine filled in its proper place, and to work it off every month or 6 weeks, for the purpose of changing the water, and ascertaining that it is in a proper working state.

I am Sir,

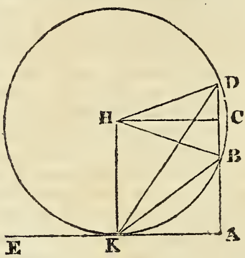
Your very humble Servant,

NAVARCHUS.

Nov. 30*th*, 1824.

SOLUTIONS OF QUESTIONS.

Quest. 39, solved Geometrically by A. Mackinnon, *Sheffield.* (See page 288.)



Let A B be the height of the pillar, and B D the height of the statue upon its top. Bisect B D in C, and draw C H perpendicular to A C, and with the centre B and distance A C, describe an arc cutting C H in H; then with the centre H and distance B H=A C, describe the circle DBK. Join K B, K D, H B, H C, and H D, when B K D, or B H C is the greatest possible, it is evident that the angle H B C will be the least possible; and the line H C, as also H B or H K, the radius of the circle, will be the least possible when it is perpendicular to A K, in which case A K will be a tangent to the circle at the point K; therefore when the angle B K D or B H C is the greatest possible, B H=H K or A C, and is therefore given. By (Euclid, 1 ft. 47) $CH^2 = BH^2 - BC^2$ or $CH = \sqrt{BH^2 - BC^2} = \sqrt{24000} = 154\cdot9161$; and the angle B H C or B K D is found to be $1^\circ\ 50'\ 51''$.

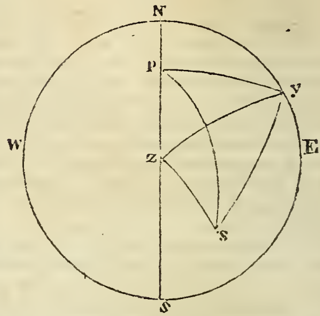
This question was also solved geometrically by Mr. Whitcombe, *Cornhill*, who supplied the solution at page 288.

Quest. 47, *answered by* T. D. *Bristol (the proposer).*

Having reduced the sun's declination, there are given in a spherical triangle, the co-latitude, the co-declination, and the hour angle, to find the sun's true altitude= $51^\circ\ 24'\ 8''\cdot824$, this corrected for semidiameter, refraction, and parallax, gives the apparent altitude of the sun's upper limb= $51^\circ\ 40'\ 42''\cdot624$. Now, by the laws of Optics, the angle of incidence is equal to the angle of reflection; therefore there are in a right angled plain triangle given the above angle, and the height of the observer's eye, to find the horizontal distance=105·27617 feet as required.

Quest. 49, *answered by* Q. Q. *Portsea (the proposer).*

Let N W S E represent the rational horizon,



N S the celestial meridian, Z the zenith, P the pole, S the sun, and y the object in the horizon. Then, since the apparent altitude and declination of S are given, Z S, P S the zenith, and polar distances, are known; also the zenith distance Z y of y is known, being manifestly 90″, and the angle S Z y, and P y the polar distance of y are given. Then the latitude may be computed as follows:—In the first place, with Z S, Z y and the angle S Z y find the third side S y.

2. P S, S y, and P y, are given to find the angle P S y, and with Z S, S y, and Z y, compute the angle Z S y. The sum or difference of the two angles; viz. the angles P S y, Z Sy (according to circumstances) is the angle Z S P,

Lastly, knowing Z S, P S, and the included angle Z S P, the arc Z P may be found, which is the colatitude; the complement of which is the latitude of the place.

QUESTION FOR SOLUTION.

Quest. 54, *proposed by* Fr—d F—lk—wo—th.

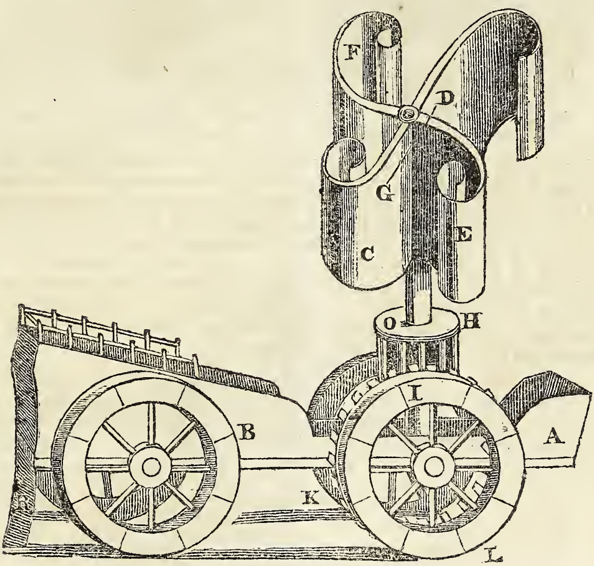
I want to plan a hexagonal flower-garden, so as to have walks from the middle of the sides through the centre, and also a walk round it, that the area of the walks may be double that of the beds: required the size of the garden, when all the walks are 2 feet in breadth.

PNEUMATICS.

In our last article on Pneumatics, we gave a description of the most common and approved wind-mills, with directions for their construction and management; in the present article we shall give a short account of several other machines which have been constructed, with the view of being moved by the same agent. Among these may be mentioned the

SAILING CHARIOT.

The following figure represents a chariot intended to be moved by the wind.

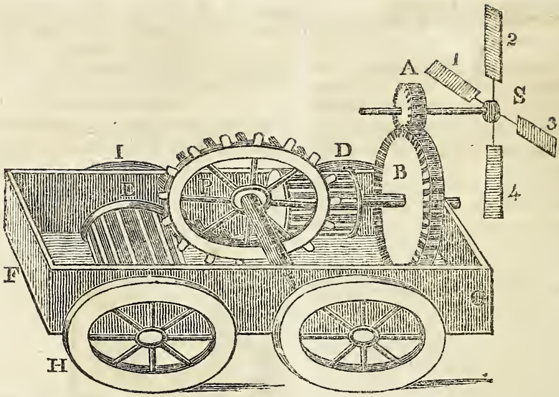


Here A B is the body of the chariot, and C D E F horizontal sails, so contrived, that the sails D facing the wind may expand, and those going from the wind may contract. The sails are turned about by the wind coming in any direction. These sails turn the axis, and trundle G H, and the trundle turns the wheel I L by the cogs in it. Therefore the chariot may move in any direction. R is a rudder to steer with.

Suppose the chariot to go against the wind. Let D be the centre of pressure of tho two sails C D the wind blows on. And let the power, (that is, the force of the wind acting against the sails) be I, then the force acting against the teeth in I L, is $\frac{GD}{OH}$. And this force being I, the force at L is also I; therefore the power at D to the force at L, is as I to $\frac{GD}{OH}$; or as O H to G D. Now, since the mast is strained by the power falling on the sails, therefore by this power O H, the chariot is urged backward. And by the force at L which is G D, it is urged forward. Let R be the force of the wind upon the body of the chariot, together with the friction in moving. Therefore, if G D is greater than the radius O H + R, the chariot will move forward against the wind; if less, backward. But if they be equal, it will stand still.

SAILING WAGGON.

Waggons have also been constructed upon the same principle, with the intention of making them sail against the wind. One of these waggons is represented by the following figure.

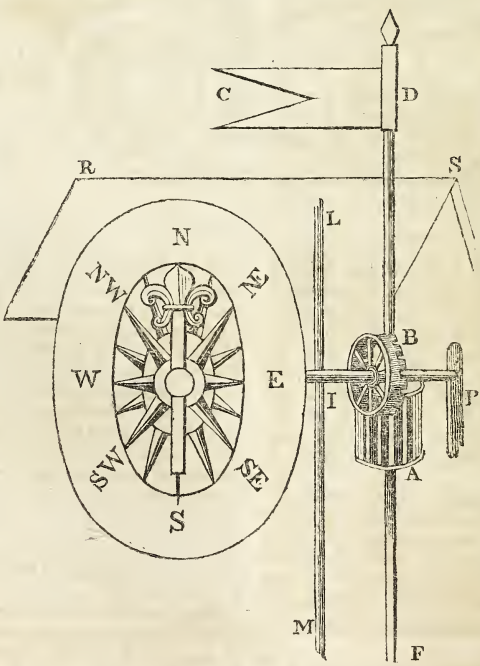


F G is the chariot, and S the sails of a wind-mill, turning in the order 1, 2, 3. As the sails go round, the pinion A moves B, and the trundle C moves D, which has both teeth and cogs. D by its teeth moves E; and the trundle E fixed to the axle-tree, carries round the wheels H I, which move the waggon in the direction H G.

The sails are set at an angle of 45°, so the force to turn them, and the force in the direction of the axis, will be equal. This waggon will always go against the wind, provided you give the sails power enough, by the combination of the wheels. But then its motion will be so much slower.

OF THE ANEMOSCOPE.

The Anemoscope is a machine for showing the changes or turnings of the wind. This machine is represented by the following figure.



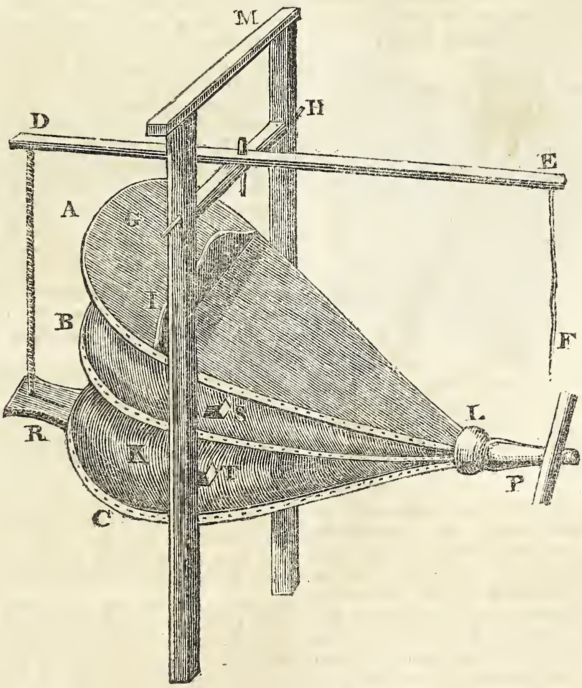
Here C D is a weathercock of thin metal, fixed fast to the long perpendicular axis D F, which turns with the least wind upon the foot F, and goes through the top of the house R S. To this axis is fixed the pinion A, which works in the crown wheel B, of an equal number of teeth. The crown wheel is fixed on the axis P I, on the end of which the index N S is fixed. The axis P I goes through the wall L M, against the wall is placed the circle N E S W, with the points of the compass round it. Then, if the vane C D be set to the north, and at the same time the index S N fixed on the axis P I, to point at S, then, however, the wind varies, it will turn the vane C D, and pinion A, and also turn the wheel D with the index N; so that the index will always be directed to the opposite point of the compass to the vane D G, or to the same as the wind is in.

Having now noticed most of the machines moved by the wind, we shall here make a few observations on a machine, commonly employed to produce a blast of wind, for purposes to which wind, as produced by nature, has never yet been applied.

WIND BELLOWS.

Bellows are commonly made of boards connected by leather, so as to allow of alternately increasing and diminishing the magnitude of their cavities, the air being supplied without by a valve. The blast must be intermitted while the air is replenished; and in order to avoid this inconvenience, a second cavity is sometimes added, and loaded with a weight, which preserves the continuity of the steam. If great uniformity be required in the blast, it will be necessary to take care that the cavity be so formed, as to be equally diminished, while the weight descends through equal spaces; but notwithstanding this precaution, there must always be an additional velocity, while the new supply of air is entering from the first cavity.

Bellows of this kind are represented by the following figure A C L.



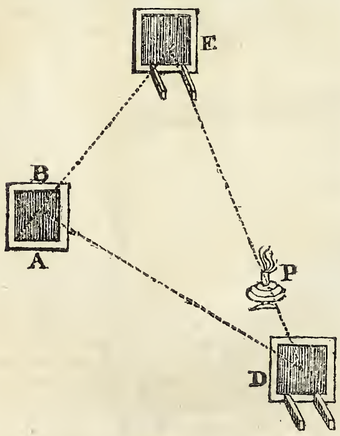
Where A L, B L, and C L are three boards, the middle board B L dividing the internal space into two parts. In the middle board is a valve S, opening into the upper part; and in the lowest board is another valve T opening into the under part. The pipe P communicates only with the upper cavity. D E a leaver moveable about the axis G H. At I a weight is laid upon the upper board to make it fall. The bellows is fixed in the frame M K by two iron pins, which are fast in the middle board, and the pipe P lies upon the earth. When the end E is pulled down by the rope E F, the end D is raised, and the rope or chain D R raises the lower board C L;

this shuts the valve T and opens S, and the air is forced into the upper cavity, which raises the upper board, and blows through the pipe P. And when E is raised, the boards A and C descend, and the valve S shuts, and T opens. And the weight I forces the air still out of the pipe, whilst more air enters in at the valve T; which, when C ascends, is forced again through the valve S as before. And thus the bellows have a continual blast.

OPTICS.

ON PHOTOMETRY, OR THE MEASURE OF LIGHT.

Photometry signifies the art of measuring light; and though the term photometer has been introduced as the name of an instrument for accomplishing this object, yet we can scarcely say that such an instrument exists. In order to measure the quantity of light lost by reflection, Bouguer placed the reflecting surface to be tried at B, as represented in the following figure,



and by means of a lamp or candle at P, he illuminated two tablets, D E, parallel to one another, and having precisely the same degree of whiteness. He then placed his eye at A, so that he could see at the same time the tablet E *directly*, and the image of the tablet D reflected from the mirror B. When the direct and reflected images were brought into contact, so that the eye could compare together their degrees of illumination, he caused the candle to be moved along the line E D, so as to throw more or less light upon either of them, till the intensity of their light appeared perfectly equal. The square of the distances E P, and D P, afforded an expression of the diminution of the light by reflection. An ingenious method of measuring the comparative intensities of the light emitted by luminous bodies, was proposed in the year 1794, by Count Rumford. The two burning candles, or lamps, or any other two lights which were to be compared, are placed at equal heights on two moveable stands, in a darkened room. A sheet of clean white paper, equally spread out, is fastened on the wainscot on one side of the room, at the same height from the floor as the lights; and the lights are placed over against this sheet of paper, at the distance of six or eight feet from it, and six or eight feet from each other, in such a manner that a line drawn from the centre of the paper, perpendicular to its surface, shall bisect the angle formed by lines drawn from the lights to that centre. In this case, the one light will be in the line of reflection of the other, the sheet of paper being considered as a plane reflecting mirror.

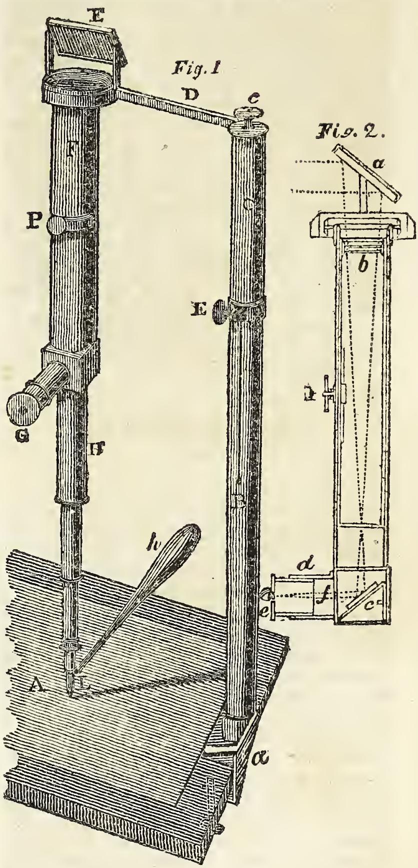
When this adjustment is made, a cylinder of wood, about six inches long, and one-fourth of an inch in diameter, is held vertically about two or three inches before the centre of the sheet of paper, so that the two shadows of the cylinder produced by the two lights may be distinctly seen. If these shadows have unequal densities, the light whose corresponding shadow is the densest, must be removed farther off, or the other must be brought nearer to the paper, till the densities of the shadows appear exactly equal; or, what is the same thing, till the densities of the rays diverging from the two lights, are equal at the surface of the paper. When this happens, the squares of the distances of the lights will be to each other as the real intensities of the lights.

In order to convert this instrument into a photometer, Count Rumford received the shadows of the cylinder on the back part of a wooden box, open in front to receive the light. Having found it inconvenient, however, to compare two shadows projected by the same cylinder, he made use of two cylinders fixed perpendicularly to the bottom of the box, and distant from the back of it $2\frac{7}{10}$ths inches, while their axes were placed at the distance of three inches. These two cylinders projected four shadows on the back of the box, (called the *field* of the instrument,) two of which are in contact exactly in the middle of the field, and are the two whose densities are to be compared; the two outer ones being made to disappear, by falling without the field on a blackened surface. In one of Count Rumford's instruments the cylinders are $\frac{4}{10}$ths of an inch in diameter, and $2\frac{7}{10}$ths inches high, and the field is $2\frac{7}{10}$th inches wide. In this instrument the paper which forms the field is pasted on a small frame of very fine ground glass, and the glass thus covered is let down into a groove made to receive it in the back of the box. For the purpose of making the shadows always of the same diameter, which is not the case unless the lights have the same diameter, the cylinders are moveable about their axes, and to each is added a vertical wing $\frac{11}{20}$ths of an inch wide, $\frac{1}{18}$th of an inch thick, of the same height with the part of the cylinder within the box, and firmly fixed to it from the top to the bottom. By means of these wings, the widths of the shadows are augmented, so as to fill the whole field of the photometer. The cylinders, which are made of brass, are turned round by taking hold of the ends which project below the bottom of the box.

For a full account of this instrument, we must refer the reader to the *Philosophical Transactions* for 1794.

The celebrated M. Lambert first suggested the thermometrical photometer, an instrument which measures the intensity of light, on the supposition that the quantity of light and heat in any beam of the solar or other rays, are invariably proportional to each other. He saw, however, the imperfections of the instrument, and remarked that its use was too circumscribed, as it was impossible to measure with a thermometer the brightness of the lunar rays.

The same principle was afterwards applied by Mr. Leslie to an air thermometer, but for the reason assigned by Lambert, it can never be considered as affording a measure of light.



DESCRIPTION OF THE OPTIGRAPH.

The optigraph is a telescope made for the purpose of copying landscapes. It was originally suggested by Dr. Darwin, and improved by Mr. Watt, who put it into the hands of the celebrated Mr. Ramsden, for the purpose of being constructed.

The optigraph, as constructed by Mr. Ramsden, was afterwards improved by Mr. Thomas Jones, who has given the following description of it.

Fig. 1st, is a perspective view of the optigraph.

A represents the drawing board, on the outside frame of which is fixed the pillar of the instrument B, by a clamp *a;* C is a tube (sliding in the pillar) on the top of which is fixed, by means of a screw *c*, the frame D; at the end of this frame is a plane mirror E, beneath which is suspended, by a universal joint, the telescope F, of which G is the eye-tube; H are sliding tubes, capable of being shortened or lengthened in the same proportion as the inside speculum *c*, as in the following figure, which is fixed to any place by the clamp screw E. The pencil L, of which *h* is the handle, slides perfectly easy, without shake, in the tubes H, and is so contrived as to have all the freedom of a pen when held in the hand for use.

Fig. 2d, represents a section of the telescope, being the principal part of the invention. The rays from an object entering the plane mirror *a*, are reflected into the telescope, passing through the object-glass *b*, and entering the speculum *c*, are reflected through the eye-glass *d*, to the eye at *e: f* is a piece of parallel glass, with a small dot on its centre, exactly in the focus of the eye-glass *d*.

Fix the drawing board to the table, (by a clamp which is packed in the box) so that the surface of the mirror E is nearly parallel to the object; then take hold of the handle *h*, and hold the pencil on that part of the paper, where you would wish the centre of your drawing, or any part of it, to be. Then place your eye at the eye-tube G, and with your left hand alter the inclination of the mirror E, until the small dot described at *f* in Fig. 2d, is on some particular part of the object that you wish to begin with, adjusting the telescope to distinct vision, by the milled head P. Then by moving your hand (having the pencil) you pass the dot seen in the field of the telescope over the object, the pencil marking it at the same time on the paper.

To make your drawing larger, pull out the tube of the pillar C, Fig. 1st, and fix it with the screw *e;* then pull out the sliding tubes H, till the pencil is within half an inch of the paper (in the middle of the board,) and proceed as formerly.

To make the drawing smaller, shorten the tubes *c* and H, by sliding them in, and proceed as before.

CHEMISTRY.

OF GOLD.

If a narrow slip of gold leaf be put, with both ends hanging out a little, between two glass plates tied together, and a strong electrical explosion be passed through it, the gold leaf is missing in several places, and the glass is tinged of a purple colour by the portion of the metal which has been oxidized. This curious experiment was first made by Dr. Franklin; it was confirmed in 1773 by Camus. The reality of the oxidizement of gold by electricity was disputed by some philosophers, but it has been put beyond the reach of doubt by the experiments of Van Marum. When he made electric sparks from the powerful Teylerian machine pass through a gold wire suspended in the air, it took fire, burnt with a green-coloured flame, and was completely dissipated in fumes, which when collected proved to be a purple-coloured oxide of gold. This combustion, according to Van Marum, succeeded not only in common air, but also when the wire was suspended in hydrogen gas, and other gasses which are not capable of supporting combustion. The combustion of gold is now easily effected by exposing gold-leaf to the action of the galvanic battery. Dr. Thomson made it burn with great brilliancy, by exposing a gold wire to the action of a stream of oxygen and hydrogen gas mixed together and burning. Now in all cases of combustion the gold is oxidized. We are at present acquainted with two oxides of gold: the *protoxide* has a *purple* or violet, the *peroxide* a *yellow* colour.

Of these the *peroxide* is most easily procured; it is therefore best known. It may be procured in the following manner: equal parts of nitric and muriatic acids are mixed together,* and poured upon gold; an effervescence takes place, the gold is gradually dissolved, and the liquid assumes a yellow colour. It is easy to see in what manner this solution is produced. For it is worthy of remark, that no metal is soluble in acids till it has been reduced to the state of an oxide. There is a strong affinity between the oxide of gold and muriatic acid. The nitric acid furnishes oxygen to the gold, and the muriatic acid dissolves the oxide as it forms. When nitric acid is deprived of the greater part of its oxygen, it assumes a gaseous form, and flies off in the state of *nitrous gas.* It is the emission of this gas which causes the effervescence. The oxide of gold may be precipitated from the nitro-muriatic acid, by pouring in a little potash dissolved in water, or even by lime water. It subsides slowly, and has a yellowish brown colour, and sometimes, indeed, approaches to black. When carefully washed and dried, it is insoluble in water and tasteless. When this oxide is moderately heated, it becomes purple. A stronger heat expels the whole of the oxygen, and reduces it to the metallic state

The properties of the *protoxide* of gold are but little known. It is formed when the metal is subjected to combustion, or to the action of electricity, and likewise by exposing the peroxide to the proper degree of heat, or even by placing it in the rays of the sun. Its colour is purple. Various preparations containing it are used in the arts, which will be noticed afterwards.

Hitherto gold has been united artificially to none of the simple combustibles except phosphorus. Hydrogen and charcoal are said to precipitate it from its solutions in the metallic state.

Sulphur, even when assisted by heat, has no action on it whatever; nor is it ever found naturally combined with sulphur, as is the case with most of the other metals;—yet it can scarcely be doubted that sulphur exercises some action on gold, though but a small one: for when an *alkaline hydro-sulphuret* is dropt into a solution of gold, a *black powder* falls to the bottom, which is found to consist of gold and sulphur, either combined or intimately mixed; and when potash, sulphur, and gold, are heated together, and the mixture boiled in water, a considerable portion of gold is dissolved. Three parts of sulphur, and three of potash, are sufficient to dissolve one of gold. The solution has a yellow colour. When an acid

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* This mixture, from its property of dissolving gold, was formerly called *aqua regia* (for gold among the alchymists, was the king of metals); it is now called *nitro muriatic acid.*

is dropt into it, the gold falls down, united to the sulphur in the state of a reddish powder, which becomes gradually black.

Gold does not combine, as far as is known, with either of the simple incombustible bodies.

But gold combines readily with the greater number of the metals, and forms a variety of alloys.

This metal is so soft, that it is seldom employed in a state of purity. It is almost always mixed with small quantities of copper and silver. Goldsmiths usually announce the purity of the gold which they sell in the following manner: Pure gold they suppose divided into 24 parts, called *carats*. Gold of 24 carats means pure gold; gold of 23 carats means an alloy of 23 parts gold, and one of some other metal; gold of 22 carats means an alloy of 22 parts of gold, and two of another metal. The number of carats mentioned specifies the pure gold; and what that number wants of 24, indicates the quantity of alloy. Thus gold of 12 carats would be an alloy containing 12 parts gold, and 12 of some other metal. In this country, the carat is divided into four grains; among the Germans into 12; and by the French it was formerly divided into 32.

OF PLATINA.

Platina, or platinum, was not known by Chemists till the middle of the eighteenth century. Under this name, however, which is of Spanish origin, and signifies *little* or inferior *silver*, some white trinkets of little estimation were sold, before the metal was distinctly known. Antonio de Ulloa, a Spanish mathematician, who accompanied the members of the French academy, in their famous voyage to Peru, for the purpose of ascertaining the figure of the earth, first gave something like a precise notion of it, in the account of his voyage published at Madrid in 1748. It is observed, that Mr. Charles Wood, an English metallurgist, brought some of it from Jamaica in 1741. This gentleman related some experiments on this new metal in the Philosophical Transactions for 1749 and 1750.

These first experiments, which announced very extraordinary properties, made a great noise in Europe, at a period when the discovery of a metal, particularly one so singular as this appeared to be, was a phenomenon beyond what any one had dared to hope. The greatest Chemists of Europe were then eager to examine platina, and investigate its distinguishing characters. Scheffer, a Swedish Chemist, gave the first accurate series of experiments on this metal, in the Memoirs of the Academy of Stockholm, in 1752; in consequence of which, he ranked this metal near gold for its properties, and called it *white gold*. Lewis, an English Chemist, to whom we are indebted, among other things, for a history of silver and of gold, very complete for the time, made a very extensive and regular series of experiments on platina, which he published in the Philosophical Transactions for 1754. In the Memoirs of the Academy of Berlin, for 1757, Margraff gave an account of his experiments on this metal. All these early labours were collected and compared by Morin, in a work he published in France, in 1758, under the title of *Platina, White Gold, or the Eighth Metal.* This is a methodical compilation of all that had been done previous to that period.

After these researches, already very numerous, Achard, Guyton, Lavoisier, and Pelletier, successively published methods of obtaining platina pure, and of fusing it, and new information respecting its combinations.

From these combined labours, we have acquired a considerable knowledge of the properties of platina, though there are still many things desirable for completing the history of this metal. The Pneumatic system has done nothing with regard to platina, except teaching us to place it on a level with gold, in respect to its difficult oxidation, its little affinity for oxygen, and its consequent unalterability by the majority of other substances.

Platina, when purified, is of a less beautiful white than silver, and verging a little towards the grey colour of iron. When burnished, it has a blackish tint, and not the white lustre of silver. Its unpolished parts are somewhat grey and dull. Its appearance is not so brilliant and pleasing as that of silver, or gold: and most men, though likely to confound it with other metals, would not form from the sight of it the same idea as of those two precious metals, which attract their eyes and excite their admiration, or attach to it the same value.

This metal is the most dense and heavy of all natural substances. When it is slightly hammered or forged, its specific gravity is 21·5, and after being well hammered, it is 23.

The elasticity of platina appears to be pretty considerable. Its ductility is great; though it is far from being easily wrought, it is reduced to very slender wires, and very thin leaves. Guyton gives it the second rank in this respect, placing it between gold and silver. It is easily bended; and the resistance and cohesion of the plates fabricated of it will, at some future period, admit a great number of uses to be made of it of high importance. The same Chemist made the most accurate experiments on its tenacity, or the cohesion of its particles. In this point, he assigns it the third rank, after iron and copper, and before silver and gold.

Platina, like all other metals, heats quickly, and is a very good conductor of caloric. Borda found that its dilatation is $\frac{1}{92000}$ to a degree of Reaumur's, and $\frac{1}{116000}$ to a degree of the decimal thermometer. Of all metals it is the most intractable in the fire, and the most difficult to fuse. It goes beyond iron and manganese in this property. Guyton estimates its fusibility at a degree yet unknown, or beyond the utmost limit of Wedgewood's pyrometer. In fact, the greatest fire produced by our furnaces scarcely soften, perceptibly, the platina, in grains. At the most extreme degrees of heat, we can only agglutinate these grains together, without imparting to them a true or strong adhesion, since they may be separated by hammering. Macquer and Baumé kept several in a continued line, exposed to the constant and violent heat of a glass-house furnace; and these grains only stuck slightly to each other, for they were afterwards separated by the hand. They perceived their colour become very brilliant, when they were at a white heat. On exposing the same grains of platina, well purified, to the focus of the burning lens of the Academy, the portions placed in the centre of the focus smoked, melted at the end of a minute, and formed an homogeneous button, white and brilliant, very ductile, and capable of being cut with a knife. Guyton likewise succeeded in fusing small portions in a crucible, by the help of his reducing flux, composed of eight parts of pounded glass, one of calcined borax, and half a part of charcoal, and employing for this operation Macquer's wind-furnace. Lavoisier also fused small portions of platina in a cavity on charcoal with a blast of oxygen gas. After all these trials, there is nothing more easy than to procure little buttons of this metal thus melted; but they are in such small masses, that it is impossible to employ them in decisive experiments; and we may still say that no real and useful fusion of platina has been obtained; since, when treated by the ordinary means, it is impossible to fuse it in such a quantity as allow us to examine its properties, and employ it in experiments capable of rendering us acquainted with them. Accordingly it will appear farther on, that, to apply it to the uses already made of it, the fabrication of plates, bars, wires, vessels, &c. it has been necessary to fuse it by the help of some alloys, and separate it afterwards by forging from the metals united with it.

Platina is a very good conductor of the electric fluid and of galvanism. Its power in this respect has not been compared with that of other metals, but it appears to be very great. It has neither smell nor taste, in which it resembles silver and gold.

Platina has hitherto been found no where except in the gold mines of America, particularly in that of Santa Fé, near Carthagena, and in the bailiwick of Choco, in Peru. It is collected in the form of little grains, of a livid grey or white, the colour of which partakes of those of silver and iron. These grains are mixed with several foreign substances; among them are found gold dust, blackish ferruginous sand, grains that appear through the lens scorified like the slag of iron, and some particles of mercury.

On examining the grains of platina with a lens, some appear angular, and others rounded or flattened like some pebbles. They may be flattened under the hammer, but some fly to pieces; and these frequently appear hollow within, and contain portions of iron and a white powder. To these small grains of iron must be ascribed the property of being attracted by the magnet, observed in the grains of platina, though well separated from the ferruginous sand among them. To obtain the purest and largest grains of platina, they are sorted by hand, and the gold dust, quartz, sand, and iron, are separated from them.

It is probable that platina is not found in the earth as it is brought to us, and as it is seen in mineralogical collections. The form of grains which it exhibits is owing either to the motion of the water by which it is carried down from the mountains into the plains, or to the grinding of the mills, through which the ores of gold with which it is mingled in the native state are passed. Sometimes pretty large pieces of it have been found. No naturalist has yet described the situations or varieties of ores of platina. It is at present the least known of all metals, and perhaps the only one which, being found hitherto only in one state, been likewise discovered but in one single country.

Platina is very distinguishable by its form, colour, and specific gravity. As it is always mixed with sand and iron, and frequently with gold and quicksilver, beside the sorting by hand already mentioned, by means of which Tillet found some grains of this metal embedded in a quartz gangue, different processes are employed for its purification. It is heated red hot to volatilize the portion of mercury left by the amalgamation, by means of which gold was obtained from it. Iron is separated from it by the magnet, which frequently takes up with this attractable metal little fragments of platina. The grains are also heated with muriatic acid, which dissolves and takes up the iron. Bergman has remarked, that platina loses 0·05 of its weight by this operation. After this, nothing remains but the platina and the gold, both of which are to be dissolved in nitro-muriatic acid; and the proportions of the two metals may be found by precipitating the gold by sulphate of iron, and carefully weighing the precipitate, which, as we have before observed, is in a metallic powder.

As to operations in the great way, there is no one yet settled or practised. The Spanish government, having found that its miners debased gold with platina, and that it was difficult to discover the fraud, on account of the specific gravity and unalterableness of this compound, is said to have shut up the mines of platina; but this is an improper expression, which requires to be explained so as to leave no ambiguity or uncertainty. It appears that platina, being always found mixed with gold ore, and both being disseminated in the native state, in the same gangue, it is impossible that the mines of platina can have been shut; but as fast as this metal, which does not dissolve like gold in quicksilver, is extracted and separated, it is thrown away, or set apart, so that it is no longer met with in trade as formerly. Hence it is, that the mode of treating it in the large way has made no progress, and that no work in this new branch of metallurgy has hitherto been erected.

Accordingly, what belongs to the metallurgy of platina is nothing more than a series of operations on a larger scale than those of a simple assay, though on a much less than the usual metallurgic operations. It is by these that Carrochez, Jeannety, Chabanon, Wollaston, and several others, have accomplished the fusion, particularly by the help of arsenious acid, or what is called white arsenic, of some considerable quantities of platina; they have hammered and forged it by repeatedly heating and softening it, so as to deprive it by little and little, and at length completely, of the arsenic which rendered it fusible, and preserved its continuous and connected form, so as to admit of its being flattened, fashioned on moulds, and drawn into wire. It is by a similar operation that it has been brought to the greatest purity, reduced to the common state of other metals, and made to assume forms which may render it useful for various purposes.

As the different processes employed by most of the artists above-mentioned for purifying, fusing, and forging platina, have not yet been described, we shall here state one of the simplest which has yet been employed. Dissolve the grains in diluted nitro-muriatic acid with as little heat as possible. Decant the solution from the black matter which resists the action of the acid. Drop into it a solution of *sal ammoniac*. An orange yellow coloured precipitate falls to the bottom. Wash this precipitate; and when dry, expose it to a heat slowly raised to redness in a porcelain crucible. The powder which remains is platinum nearly pure. By redissolving it in nitro-muriatic acid, and repeating the whole process, it may be made still purer. When these grains are wrapt up in a thin plate of platinum, heated to redness, and cautiously hammered, they unite, and the whole may be formed into an ingot.

It cannot be combined with oxygen, and converted into an oxide, by the strongest artificial heat of our furnaces. Platinum, indeed, in the state in which it is brought from America, may be partially oxidized by exposure to a violent heat, as numerous experiments have proved; but in that state it is not pure, but combined with a quantity of iron. It cannot be doubted, however, that if we could subject it to a sufficient heat, platinum would burn, and be oxidized like other metals: for, when Van Marum exposed a wire of platinum to the action of his powerful electrical machine, it burnt with a faint white flame, and was dissipated into a species of dust, which proved to be the oxide of platinum. By putting a platinum wire into the flame produced by the combustion of hydrogen gas mixed with oxygen, he caused it to burn with all the brilliancy of iron wire, and to emit sparks in abundance.

To obtain the oxides of this metal, it is necessary to have recourse to the action of an acid. When the deep brown solution of platinum in nitro-muriatic acid is treated with lime water, a yellowish brown powder falls. Dissolve this powder in nitric acid; evaporate to dryness, and apply a heat sufficient to drive off the acid. The brown powder which remains is the peroxide of platinum. It is tasteless and insoluble in water. When heated to redness, the oxygen is driven off, and the oxide reduced to the metallic state. One hundred and fifteen parts of oxide, by this treatment, leave 100 parts of metal.

If the heat in this experiment be very cautiously raised, the oxide, before it is reduced, assumes a green colour. This change is occasioned by the separation of a portion of the oxygen. The green coloured powder is, according to Chenevix, a protoxide of platinum.

The action of the simple combustibles on this metal is not more remarkable than their action on gold.

Neither hydrogen nor carbon have been hitherto combined with it.

Phosphorus unites with it easily, and forms a *phosphuret*. By mixing together an ounce of platinum, an ounce of phosphoric glass, and a dram of powdered charcoal, and applying a heat of about 32° Wedgewood, Mr. Pelletier formed a *phosphuret* weighing more than an ounce. It was partly in the form of a button, and partly in cubic crystals. It was covered above by a blackish glass. It was of a silver white colour, very brittle, and hard enough to strike fire with steel. When exposed to a fire strong enough to melt it, the phosphorus was disengaged, and burnt on the surface. He found also, that when phosphorus was projected on red hot platinum, the metal instantly fused and formed a phosphuret. As heat expels the phosphorus, Mr. Pelletier has proposed this as an easy method of purifying platinum.

Platinum cannot be made to unite to sulphur by heating them together. In this respect it resembles gold; yet there seems to be an affinity between the two substances; for when the metal is heated with a mixture of potash and sulphur, it is corroded and rendered partly soluble in water, as was proved by the experiments of Lewis and Margarf. And when sulphuretted hydrogen gas is passed into a solution of platinum in an acid, the metal is thrown down in dark brown flakes, apparantly in combination with sulphur. Indeed, if we believe Mr. Proust, a sulphuret of this metal occurs sometimes mixed with native platina.

Platinum, as far as is known, does not combine with the simple incombustibles.

It combines with most of the metals, and forms alloys, which were first examined by Dr. Lewis.

ASTRONOMY.

OF THE CLOUDS.

Ye mists and exhalations that now rise
From hill or steaming lake, dusky or gray,
Till the sun paint your fleecy skirts with gold,
In honour to the world's Great Author rise,
Whether to deck with clouds th' uncoloured sky,
Or wash the thirsty earth with falling showers,
Rising or falling, still advance his praise.

MILTON.

Clouds are generally supposed to consist of vapour, which has been raised from the sea and land by means of heat. These vapours ascend till they reach air of the same specific gravity with themselves, when they combine with each other, become more dense and opaque, and then become visible.

The thinner or rarer the clouds are, the higher do they ascend in the air; however, it seldom happens that their height exceeds two miles. The greater number of clouds are suspended at the height of one mile; and when they are highly electrified, their height is not above eight or nine hundred yards.

While Don Ulloa was in South America, measuring a degree of the meridian, he was for some time stationed on the summit of Cotapaxi, a mountain about three miles above the level of the sea, where he says—the clouds could be seen at a great distance below, and that he could hear the horrid noise of the thunder and tempests, and even see the lightnings issue from the clouds far below him.

The wonderful variety observable in the colours of clouds, is owing to their particular position with respect to the sun, and the different reflections of his light. The various figures which they so readily assume, is supposed to proceed from their loose and voluble texture, revolving in any form, according to the direction and force of the wind, or to the quantity of electric matter which they contain.

About the tropics the clouds roll themselves into enormous masses, as white as snow, turning their borders into the forms of hills, piling themselves upon each other, and exhibiting the shapes of mountains, caverns, and rocks. "There," says St. Pierre, "may be perceived, amid endless ridges, a multitude of valleys, whose openings are distinguished by purple and vermillion." These celestial valleys exhibit, in their various colours, matchless tints of white, melting into shades of different colours. Here and there may be observed torrents of light issuing from the dark sides of the mountains, and pouring their streams, like ingots of gold and silver, over rocks of coral. These appearances are not more to be admired for their beauty than for their endless combinations, for they vary every instant. What, a moment before, was luminous, becomes coloured; what was coloured, mingles into shade; forming singular and most beautiful representations of islands and hamlets, arched bridges stretched over wide rivers, immense ruins, huge rocks, and gigantic mountains.

Among the Highlands of Scotland the clouds also display the finest outlines, and assume the most beautiful figures; more especially when viewed from their rugged and lofty summits.

"Clouds," says Dr. Thompson, "are not formed in all parts of the horizon at once; the formation begins in one particular spot, while the rest of the air remains clear as before; and though the greatest quantity of vapour exists in the lower strata of the atmosphere, clouds never begin to form there, but always at some considerable height." It is remarkable, says the same author, that the part of the atmosphere at which they form has not arrived at the point of extreme moisture, nor near that point, even a moment before their formation.

They are not formed, then, because a

greater quantity of vapour has got into the air than could remain there without passing its maximum. It is still more remarkable, that when clouds are formed, the temperature of the spot does not *always* suffer a diminution, although this may sometimes be the case. On the contrary, the heat of the clouds themselves is sometimes greater than that of the surrounding air. Neither, then, is the formation of the clouds owing to the capacity of air for combining with moisture being lessened by cold. So far from this being the case, we often see clouds, which had remained in the atmosphere during the heat of the day, disappear in the night, after the heat of the air was diminished.

The formation of clouds and rain, then, cannot be accounted for by the principles with which we are acquainted. It is neither to the saturation of the atmosphere, nor the diminution of heat, nor the mixture of airs of different temperatures, as Dr. Hutton supposed; for clouds are often formed without any wind at all either above or below them: and even if this mixture constantly took place, the precipitation, instead of accounting for rain, would be almost imperceptible.

It is a well-known fact, that evaporation goes on for a month or two together in hot weather without any rain. This sometimes happens in the temperate zone; and every year in the torrid zone. At Calcutta, during the month of January, in the year 1785, it never rained at all: the mean of the thermometer for the whole month was $66\frac{1}{2}$ degrees: there were no high winds, and, during the greater part of the month, scarcely any wind at all.

As the moisture which is thus raised by evaporation is not accumulated in the atmosphere, above the place from which it was evaporated, it must be disposed of in some other way; but the manner in which this is accomplished is not so well *known*. If it be carried on daily through the different strata of the atmosphere, and wafted to other regions by superior currents of air, it is impossible to account for the different electrical states of the clouds, situated between different strata, which often produce the most violent thunder storms. For vapours are conductors of the electric fluid, and, of course, would daily restore the equilibrium of the whole atmosphere through which they passed. There would, therefore, be no positive and negative clouds, and consequently no thunder storms. Clouds could not have remained in the lower strata of the atmosphere, and been daily carried off by winds to other countries; for there are often no winds at all, during several days, to perform this office; nor would the dews diminish as they are found to do when the dry weather continues for a long time.

It is impossible for us to account for this remarkable fact upon any principle with which we are acquainted. The water can neither remain in the atmosphere, nor pass through it in the state of vapour. It must, therefore, assume some other form; but what that form is, or how it assumes it, we do not know.

In order to render the study of meteorology more systematic, Mr. Luke Haward has lately introduced a scientific nomenclator, for distinguishing the various forms or modifications of clouds, which promises to be of great use in this important, but hitherto neglected, branch of physical science.

The simple forms, or modifications, are three in number, and named *Cirrus*, *Cumulus*, and *Stratus*. These are defined by Mr. Haward as follows:—The *Cirrus* is composed of parallel, flexuous, or diverging fibres, extensible in any or in all directions.

The *Cumulus*, convex or conical, heaps, increasing upwards from a horizontal base.

The *Stratus*, is a widely extended, continuous, horizontal sheet, increasing from below.

The intermediate modifications are four in number, each of which is formed from various combinations of the simple modifications just mentioned. They are the *Cirro-cumulus*, the *Cirro-stratus*, the *Cumulo-stratus*, and the *Cumulo-cirro-stratus*, or *Nimbus*; and are defined as follows.

Cirro-cumulus. Small well-defined roundish masses, in close horizontal arrangement.

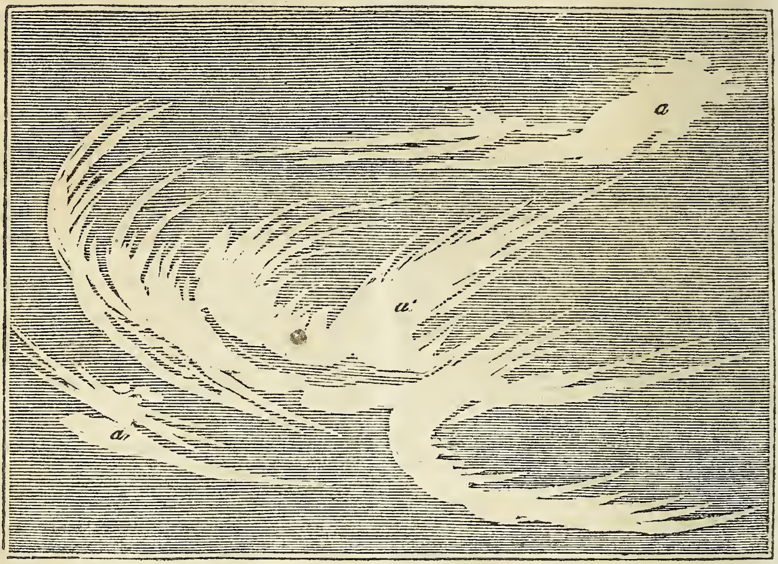
Cirro-stratus. Horizontal or slightly-inclined masses, bent downward, or undulated, separate, or in groups consisting of a number of small clouds.

Cumulo-stratus. The cirro-stratus blended with the cumulus, and either appearing intermixed with the heaps of the latter, or super-adding a wide-spread structure to its base.

Cumulo-cirro-stratus. The rain cloud. A cloud, or system of clouds, from which rain is falling. It is a horizontal sheet, above which the cirrus spreads, while the cumulus enters it laterally, and from beneath.

OF THE CIRRUS.

Clouds in this modification appear to have the least density, the greatest elevation, and the greatest variety of extent and direction. They are the earliest appearance after serene weather. They are first indicated by a few threads pencilled, as it were, on the sky. These increase in length, and new ones are in the mean time added laterally. Often the first-formed threads serve as stems to support numerous branches, which in their turn give rise to others. This modification is represented by the following figure.



The increase is sometimes perfectly indeterminate, at others it has a very decided direction. Thus the first few threads being once formed, the remainder shall be propagated either in one, two, or more directions laterally, or obliquely upward or downward, the direction being often the same in a great number of clouds visible at the same time.

Their duration is uncertain, varying from a few minutes after the first appearance to an extent of many hours. It is long when they appear alone and at great heights, and shorter when they are formed lower and in the vicinity of other clouds.

This modification, although in appearance almost motionless, is intimately connected with the variable motions of the atmosphere. Considering that clouds of this kind have long been deemed a prognostic of wind, it is extraordinary that the nature of this connection should not have been more studied, as the knowledge of it might have been productive of useful results.

In fair weather, with light variable breezes, the sky is seldom quite clear of small groups of the oblique cirrus, which frequently come on from the leeward, and the direction of their increase is to windward. Continued wet weather is attended with horizontal sheets of this cloud, which subside quickly and pass to the cirrostratus.

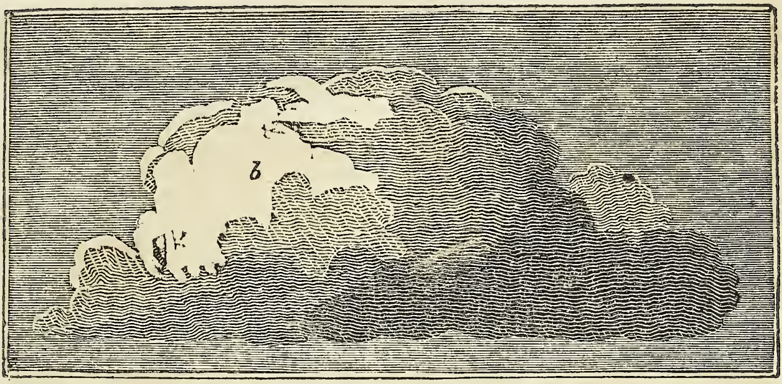
Before storms they appear lower and denser, and usually in the quarter opposite to that from which the storm arises. Steady high winds are also preceded and attended by streaks running quite across the sky in the direction they blow in.

The relation of this modification with the state of the barometer, thermometer, hygrometer, and electrometer, have not yet been attended to.

OF THE CUMULUS.

Clouds in this modification are commonly of the most dense structure: they are formed in the lower atmosphere, and move along with the current which is next the earth.

A small irregular spot first appears, and is, as it were, the nucleus on which they increase. The lower surface continues irregularly plane, while the upper rises into conical or hemispherical heaps; which may afterwards continue long nearly of the same bulk, or rapidly rise to mountains, as represented by the following figure.



In the former case they are usually numerous and near together, in the latter few and distant; but whether there are few or many, their bases always lie nearly in one horizontal plane, and their increase upward is somewhat proportionate to the extent of base, and nearly alike in many that appear at once.

Their appearance, increase, and disappearance, in fair weather, are often periodical, and keep pace with the temperature of the day. Thus they will begin to form some hours after sun-rise, arrive at their maximum in the hottest part of the afternoon, then go on diminishing, and totally disperse about sun-set.

But in changeable weather they partake of the vicissitudes of the atmosphere; sometimes evaporating almost as soon as formed, at others suddenly forming and as quickly passing to the compound modifications.

The cumulus of fair weather has a moderate elevation and extent, and a well defined rounded surface. Previous to rain it increases more rapidly, appears lower in the atmosphere, and with its surface full of loose fleeces or protuberances.

Independently of the beauty and magnificence it adds to the face of nature, the cumulus serves to screen the earth from the direct rays of the sun, by its multiplied reflections, to diffuse, and, as it were, economise the light, and also to convey the product of evaporation to a distance from the place of its origin. The relations of the cumulus with the state of the barometer, &c. have not yet been sufficiently attended to.

The formation of large cumuli to leeward in a strong wind, indicates the approach of a calm with rain. When they do not disappear or subside about sunset, but continue to rise, thunder is to be expected in the night.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF TOBIAS JOHN MAYER.

Tobias John Mayer, a very eminent German mathematician and astronomer, was born at Marbach, a small town in the duchy of Wirtemberg, on the 17th of February, 1723. He did not enjoy the advantage of a regular academical education; but his genius and application enabled him, at an early age, and without any assistance, to become a proficient in the mathematical and mechanical sciences, which he afterwards cultivated with such success as rendered his name celebrated throughout Europe. Some essays which he published in his twenty-second year attracted attention, and probably were the means of his procuring an appointment, in 1746, in the geographical establishment originally instituted by Homann at Nuremberg, where his talents were usefully employed in preparing the maps which were published by that company. His *Critical Map of Germany*, in which he corrected a multitude of errors, was particularly esteemed. He was, at the same time, admitted a member of the Cosmographical Society of Nuremberg, and contributed several memoirs to the collection published by that body, which may be considered as the precursors of his larger works on the theory of the lunar motions, and the determination of the longitude.

The highly interesting train of investigation, however, in which the genius of Mayer was now engaged, would probably never have been prosecuted to a successful issue, had he not been placed in a situation more favourable to the cultivation of science, by his appointment to the professorship of mathematics in the University of Gottingen, in the year 1751. He availed himself, with indefatigable zeal and industry, of the advantages which he now enjoyed; and he was still farther stimulated to the prosecution of his astronomical labours, when, in 1754, the principal charge of the observatory was committed to him. His unremitted exertions, however, seem to have exhausted his frame; and his death is also supposed to have been hastened by the sufferings to which the town of Gottingen was exposed during the seven-years' war. He died on the 20th of February, 1762, at the age of 39.

The services of Mayer have long been justly appreciated by men of science. His reputation is chiefly founded on the *Lunar Tables*, which he calculated with a degree of exactness till then unknown, and which he continued to improve until the day of his death. He adopted the theory of Euler, after having carefully investigated the correctness of its principles, and compared them with the results of his own accurate observations. About this period the attention of men of science in England had been directed to the discovery of some means of determining the longitude at sea, for which a considerable reward had been offered during the reign of Queen Anne. As Mayer's lunar tables seemed to afford the means of attaining this object, he was encouraged to lay claim to the reward, and accordingly transmitted a copy of his tables to the Lords of the Admiralty in 1755. He did not live, however, to reap the reward of his services; but the accuracy and utility of his labours were acknowledged, and his widow received £3000, being a part of the sum which had been offered for the discovery of the longitude.

The principles upon which Mayer proceeded in constructing these tables are developed in the two following works: *Theoria Lunæ juxta Systema Newtonianum*, London, 1767, 4to. and *Tabulæ motuum Solis et Lunæ*, ibid. 1770, 4to. These tables, however, had been previously published in the *Memoirs of the Royal Society of Gottingen* during the author's lifetime, and were afterwards several times reprinted with improvements.

Mayer also delineated, with great neatness and accuracy, a new map of the moon's disc; and he made some important observations on the peculiar motions of the fixed stars, besides constructing an improved catalogue of 992 of these bodies. His manuscripts, which, in addition to the matters already mentioned, contained some treatises on physical subjects, were purchased by the government for the university of Gottingen, and preserved in the observatory. Lichtenberg began to collect and to publish Mayer's unprinted treatises, but of this work only one volume appeared, entitled *Opera inedita.*

UNIFORMITY OF WEIGHTS AND MEASURES.

(*Continued from page* 382.)

" VI. And be it further enacted, That from and after the first day of *May* one thousand eight hundred and twenty-five, the standard measure of capacity, as well for liquids as for dry goods not measured by heaped measure, shall be the gallon, containing ten pounds avoirdupois weight of distilled water weighed in air, at the temperature of sixty-two degrees of *Fahrenheit's* thermometer, the barometer being at thirty inches; and that a measure shall be forthwith made of brass, of such contents as aforesaid, under the direction of the Lord High Treasurer, or the Commissioners of his Majesty's Treasury of the United Kingdom, or any three or more of them for the time being; and such brass measure shall be and is hereby declared to be the imperial standard gallon, and shall be and is hereby declared to be the unit and only standard measure of capacity, from which all other measures of capacity to be used, as well for wine, beer, ale, spirits, and all sorts of liquids, as for dry goods not measured by heaped measure, shall be derived, computed, and ascertained; and that all measures shall be taken in parts or multiplies, or certain proportions of the said imperial standard gallon; and that the quart shall be the fourth part of such standard gallon, and the pint shall be one-eighth of such standard gallon, and that two such gallons shall be a peck, and eight such gallons shall be a bushel, and eight such bushels a quarter of corn or other dry goods, not measured by heaped measure.

" VII. And be it further enacted, That the standard measure of capacity for coals, culm, lime, fish, potatoes, or fruit, and all other goods and things commonly sold by heaped measure, shall be the aforesaid bushel, containing eighty pounds avoirdupois of water as aforesaid, the same being made round with a plain and even bottom, and being nineteen inches and a half from outside to outside of such standard measure as aforesaid.

" VIII. And be it further enacted, That in making use of such bushel, all coals and other goods and things commonly sold by heaped measure shall be duly heaped up in such bushel, in the form of a cone, such cone to be of the height of at least six inches, and the outside of the bushel to be the extremity of the base of such cone; and that three bushels shall be a sack, and that twelve such sacks shall be a chaldron.

"IX. Provided always, and be it enacted, That any contracts, bargains, sales, and dealings, made or had for or with respect to any coals, culm, lime, fish, potatoes, or fruit, and all other goods and things commonly sold by heaped measure, sold, delivered, done or agreed for, or to be sold, delivered, done, or agreed for by weight or measure, shall and may be either according to the said standard of weight, or the said standard of heaped measure; but all contracts, bargains, sales, and dealings, made or had for any other goods, wares, or merchandize, or other thing done or agreed for, or to be sold, delivered, done or agreed for by weight or measure, shall be made and had according to the said standard of weight, or to the said gallon, or the parts, multiples, or proportions thereof; and in using the same the measures shall not be heaped, but shall be stricken with a round stick or roller, straight and of the same diameter from end to end.

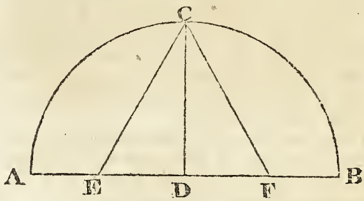
"X. Provided always, and be it enacted, That nothing herein contained shall authorize the selling in *Ireland*, by measure, of any articles, matters, or things which by any law in force in *Ireland* are required to be sold by weight only.

"XI. And be it further enacted, That copies and models of each of the said standard yard, the said standard pound, the said standard gallon, and the said standard for heaped measure, and of such parts and multiples thereof respectively, as the Lord High Treasurer of the United Kingdom of *Great Britain* and *Ireland*, or the said Commissioners of His Majesty's Treasury, or any three of them for the time being, shall judge expedient, shall, within three calendar months next after the passing of this Act, be carefully made and verified under the direction of the said Lord High Treasurer, or the Commissioners of His Majesty's Treasury, or any three of them for the time being; and that the copies and models of the said standard yard, of the said standard pound, of the said standard gallon, and of the said standard for heaped measure, and of parts and multiples thereof, so forthwith to be made and verified as aforesaid, shall, within three calendar months after the passing of this Act, be deposited in the office of the Chamberlains of the Exchequer at *Westminster*, and that copies thereof, verified as aforesaid, shall be sent to the Lord Mayor of *London*, and the Chief Magistrate of *Edinburgh* and *Dublin*, and of such other cities and places, and to such other places and persons in His Majesty's dominions or elsewhere, as the Lord High Treasurer or Commissioners of the Treasury may from time to time direct.

SOLUTIONS OF QUESTIONS.

QUEST. 50, *answered by* MR. WHITCOMBE, *Cornhill.*

Let A C B be the semicircle, and let E C F be the triangle.



Then put $x =$ D E or D F half the base of the triangle, then it is evident that $2x =$ E F = E C or C F; put also $3m =$ C D, or A D and by Euc. 47, and 1. $\sqrt{DE^2 + DC^2}$ = C E, that is, $\sqrt{x^2 + 9m^2} = 2x$. Now this squared becomes $x^2 + 9m^2 = 4x^2$, or $3x^2 = 9m^2$, or $x^2 = 3m^2$. Hence $x = m\sqrt{3}$, and $2x = 2m\sqrt{3}$; that is C E = $\frac{AB}{3}\sqrt{3}$ Q. E. I.

This question was also answered by Mr. J. HOLROYD, *Oldham;* and the proposer.

QUEST. 51, *answered by* I. C. S. *Church Row.*

Here the diameter of the ceiling is 30 feet, × 3·1416, gives the perimeter: and ¼ of the perimeter multiplied by 5, the height of arch, and again by 5 the projection of ditto, and by 3·1416, gives 1850·55498, call this product A. Then the square of difference of the diameter of the room and ceiling × ·7854, and again by ⅔ of the height of the arch = 261·79999, call this product B: then square the diameter 30, multiply by ·7854 and again by the height of the arch, gives 3534·3 call this product C—lastly square the diameter of the room multiply by ·7854, and again by 20 the height of the room to spring of the arch = 21532·8, and this added to the sum of A, B, and C, gives the content in cubic feet = 30779·45947 as required.

This question was also answered by MR. J. TAYLOR; MR. GEO. FULVOYE; MR. STEPHENS; and by the proposer, who appears to have taken the question from Bonnycastle's Mensuration.

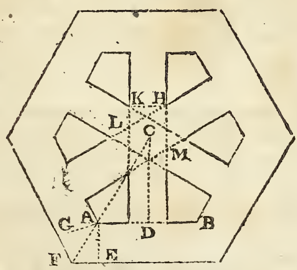
QUEST. 53, *answered by* MR. J. HARDING, *Hart Street.*

Put $x+y$ and $x-y$ for the respective deposits. Then by question their sum $2x = £3·3$; hence $x = £1·65$. Also by the question $x+y$ and $x-y$ involved to their 5th powers, become by addition $2x^5 + 20x^3y^2 + 10xy^4 = £43·32933$, or $x^5 + 5xy^4 + 10x^3y^2 = £43·32933$, which by substituting the value of x or 1·65, dividing, and transposing, gives $y^4 + 5·445y^2 = 1·14361875$; then by completing the square and extracting the root $y^2 + 2·7225 = \sqrt{8·555625} = 2·925$. Whence $y^2 = ·2025$ and $y = ·45$. Consequently John's or the greatest deposit is $x+y = £1·65 + ·45 = £2$ 2. and $x-y$ or Thomas's deposit is $1·65 - 45·$ £1 4.

This question was also correctly answered by MR. J. WHITCOMB, *Cornhill;* MR. J. TAYLOR, *Clement's Lane;* J. C. S. *Church Row;* and by the proposer.

QUEST. 54, *answered by* FR—D F—LK—WO—TH (*the Proposer.*)

Let the annexed figure represent the garden.



Put a = the breadth of the walks = KH, c = the tabular number for the hexagon = 2·598076, x = the side of the garden = A B; then, because in the hexagon CA = AB, $\sqrt{\frac{3x^2}{4}}$ = C D = ½ the length of the walks ∴ the area of the centre walks, is $3a \times ·2\sqrt{\frac{3x^2}{4}}$, twice the rhomboides, formed by the crossing of the roads LM; the side of which may be found thus, because the least figure of which C is the centre is a heptagon, the sides of which being produced to the apex K, will form a triangle equal, and equiangular to those within, of which the figure is composed; but they are equilateral, and their angles are = 60° ∴ the angle K L H of the triangle K L H, is = 60°. Now by Trig. As the natural sine of the ∠ K L H = 60° = 86603 : K H = 2 : : the ∠ H K L = 90 = 100000 : H L = 2·3088114, which let = b; then $6a\sqrt{\frac{3x^2}{4}} - 2ab$, is the area of the centre walks: Now to find the area of the outer walk, by similar triangle $CD = \sqrt{\frac{3x^2}{4}}$: $AD = \frac{x}{2}$: : $AE = a$: E F or $GF = \dfrac{\frac{ax}{2}}{\sqrt{\frac{3x^2}{4}}} = \frac{a}{2}$ now this multiplied into $AE = a$ will be = the area of the figure A G F E, because the trian. A E F is = the trian. A G F; —now the outer walk is composed of 6 times xa + 6 times the fig. A G F E ∴ per question we have $6ax + 3a^2 + 6a.\sqrt{\frac{3x^2}{4}} - 2ab = 2cx^2 - 12a.\sqrt{\frac{3x^2}{4}} - 4\overline{ab}$, now by dividing by 2 and transposing the terms, $cx^2 - 3ax - 9a.\sqrt{\frac{3x^2}{4}} = \frac{3}{2}a^2 + ab$ from which $x^2 - \left(\frac{a.\sqrt{\frac{234}{4}} - 3a}{c}\right)x = \frac{2ab+3a^2}{c}$: Let $a\sqrt{\frac{243}{4}} - 3a = d$ then is $x = \sqrt{\frac{2ab+3a^2}{c} + \frac{d^2}{4}} + \frac{d}{2} = 4·599$ feet = the side required.

This question was also answered by Mr. WHITCOMBE; but his answer was 5·575 feet.

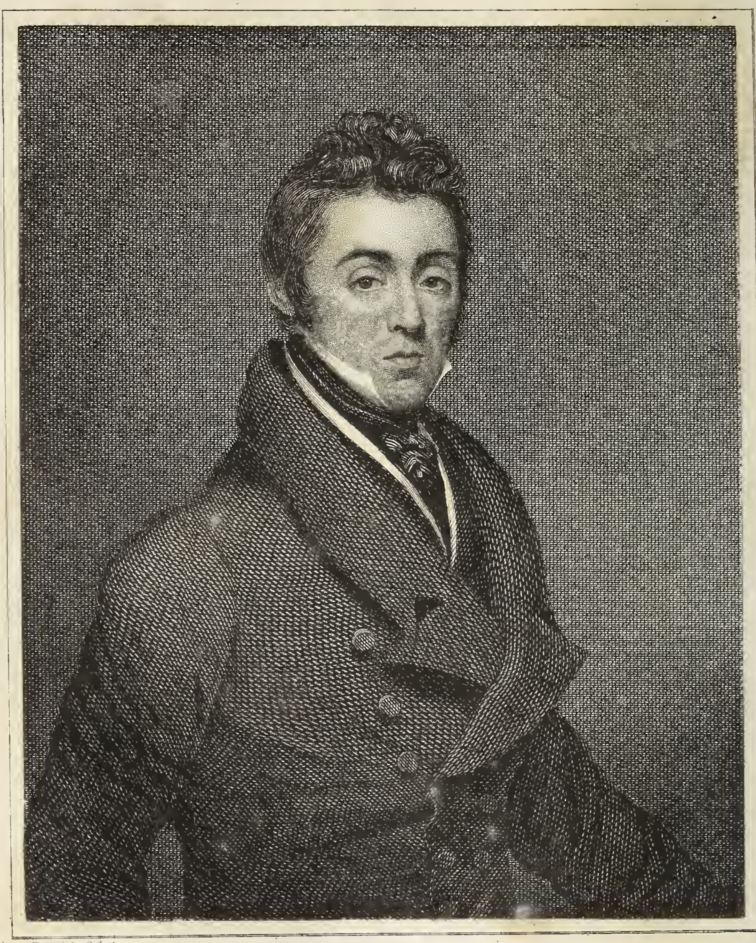
QUESTIONS FOR SOLUTION.

QUEST. 55, *proposed by* MR. J. HOLROYD, *Oldham.*

There are three towns A, B, C, the distance of the towns A, C is 20 miles, and the roads from A, to B and C form a right angle. Now two travellers set out at the same time from the towns A and C, to go to the town B; the traveller in the road A B goes at the uniform rate of 4 miles an hour, and the other at the uniform rate of 5 miles an hour, and the former arrives at the town B just half an hour before the other. Required the distance of the towns A, and C, from the town B, geometrically.

QUEST. 56, *proposed by* MR. J. TAYLOR, *Clement's Lane, Lombard Street.*

Fig, the grocer, borrows of Premium a certain sum, and per agreement, pays Premium double the usual annual interest, during Premium's life: but at his death the principal to be Fig's. Quere how long ought Premium to live so that Fig will be neither a gainer nor loser?



Paint.d by C. Ambrose.

GEO. G. CAREY.

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—1825—

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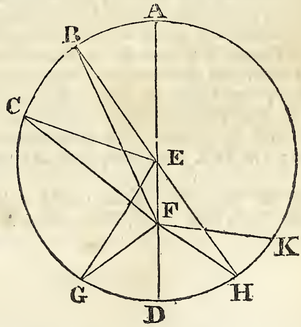
GEOMETRY.

PROPOSITION VII.

THEOREM.—*If any point be taken in the diameter of a circle, which is not the centre, of all the straight lines which can be drawn from it to the circumference, the greatest is that in which the centre is, and the other part of that diameter is the least; and, of any others, that which is nearer to the line passing through the centre is always greater than one more remote from it: And from the same point there can be drawn only two straight lines that are equal to one another, one upon each side of the shortest line.*

Let A B C D be a circle, and A D its diameter, in which let any point F be taken which is not the centre: let the centre be E; of all the straight lines F B, FC, F G, &c. that can be drawn from F to the circumference, F A is the greatest, and F D, the other part of the diameter A D, is the least; and of the others, F B is greater than F C, and F C than F G.

Join B E, C E, G E; and because two sides of a triangle are greater than the third, B E, E F are greater than B F; but A E is equal to E B; therefore A E, E F, that is, A F is greater than B F: again, because B E is equal to C E, and F E common to the triangles B E F, C E F, the two sides B E, E F are equal to the two C E, E F; but the angle B E F is greater than the angle C E F; therefore the base B F is greater than the base F C; for the same reason, C F is greater than G F. Again, because G F, F E are greater than E G, and E G is equal to E D; G F, F E are greater than E D: take away the common part F E, and the remainder G F is greater than the remainder F D; therefore F A is the greatest, and F D the least of all the



straight lines from F to the circumference; and B F is greater than C F, and C F than G F.

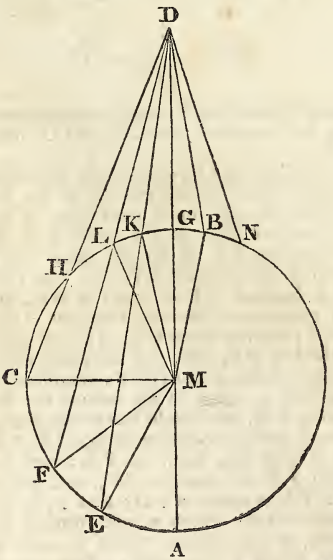
Also there can be drawn only two equal straight lines from the point F to the circumference, one upon each side of the shortest line F D: at the point E in the straight line E F, make the angle F E H equal to the angle G E F, and join F H: Then, because G E is equal to E H, and E F common to the two triangles G E F, H E F; the two sides G E, E F are equal to the two H E, E F; and the angle G E F is equal to the angle H E F; therefore the base F G is equal to the base F H: but besides F H, no straight line can be drawn from F to the circumference equal to F G: for, if there can, let it be F K; and because F K is equal to F G, and FG to F H, F K is equal to F H; that is, a line nearer to that which passes through the centre, is equal to one which is more remote, which is impossible. Therefore, if any point be taken, &c. Q. E. D.

PROPOSITION VIII.

THEOREM.—*If any point be taken without a circle, and straight lines be drawn from it to the circumference, whereof one passes through the centre; of those which fall upon the concave circumference, the greatest is that which passes through the centre; and of the rest, that which is nearer to that through the centre is always greater than the more remote: But of those which fall upon the convex circumference, the least is that between the point without the circle, and the diameter; and of the rest, that which is nearer to the least is always less than the more remote: And only two equal straight lines can be drawn from the point to the circumference, one upon each side of the least.*

Let A B C be a circle, and D any point without it, from which let the straight lines D A, D E, D F, D C be drawn to the circumference, whereof DA passes through the centre Of those which fall upon the concave part of the circumference A E F C, the greatest is A D which passes through the centre; and the nearer to it is always greater than the more remote; viz. D E than D F, and D F than D C: but of those which fall upon the convex circumference H L K G, the least is D G between the point D and the diameter A G; and the nearer to it is always less than the more remote; viz. D K than D L, and D L than D H.

Take M the centre of the circle A B C, and join M E, M F, M C, MK, M L, M H:



And because A M is equal to M E, if M D be added to each, A D is equal to E M and M D; but E M and M D are greater than E D; therefore also A D is greater than E D. Again, because M E is equal to M F, and M D common to the triangles E M D, F M D: E M, M D are equal to F M, M D; but the angle E M D is greater than the angle F M D; therefore the base E D is greater than the base F D. In like manner it may be shown, that F D is greater than C D. Therefore D A is the greatest; and D E greater than D F, and D F than D C.

And because M K, K D are greater than M D, and M K is equal to M G, the remainder K D is greater than the remainder G D; that is, G D is less than K D: And because M K, D K are drawn to the point K within the triangle M L D from M D, the extremities of its side M D; M K, K D are less than M L, L D, whereof M K is equal to M L; therefore the remainder D K is less than the remainder D L: In like manner, it may be shown that D L is less than D H: Therefore D G is the least, and D K less than D L, and D L less than D H.

Also there can be drawn only two equal straight lines from the point D to the circumference, one upon each side of the least: at the point M, in the straight line M D, make the angle D M B equal to the angle D M K, and join D B; and because in the triangles K M D, B M D, the side K M is equal to the side B M, and M D common to both, and also the angle K M D equal to the angle B M D, the base D K is equal to the base D B. But, besides D B, no straight line can be drawn from D to the circumference, equal to DK: for, if there can, let it be D N; then, because D N is equal to D K, and D K equal to D B, D B is equal to D N; that is, the line nearer to D G, the least, equal to the more remote, which has been shown to be impossible. If, therefore any point, &c. Q. E. D.

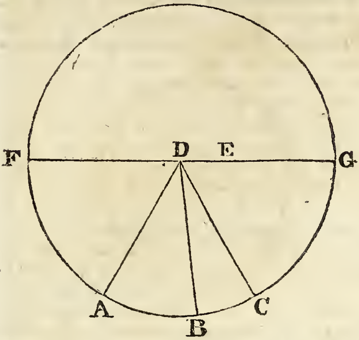
PROPOSITION IX.

THEOREM.—*If a point be taken within a circle, from which there fall more than two equal straight lines upon the circumference, that point is the centre of the circle.*

Let the point D be taken within the circle A B C, from which there fall on the circumference more than two equal straight lines; viz. D A, D B, D C, the point D is the centre of the circle.

For, if not, let E be the centre, join D E and produce it to the circumference in F, G; then F G is a diameter of the circle A B C: And because in F G, the diameter of the circle A B C, there is taken the point D which is not the centre, D G shall be the greatest line from it to the circumference, and D C greater than D B, and

D B than D A; but they are likewise

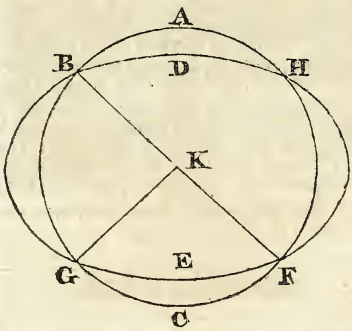


equal, which is impossible: Therefore E is not the centre of the circle A B C: In like manner, it may be demonstrated, that no other point but D is the centre; D therefore is the centre. Wherefore, if a point be taken, &c. Q. E. D.

PROPOSITION X.

THEOREM.—*One circle cannot cut another in more than two points.*

If it be possible, let the circumference F A B cut the circumference D E F in more

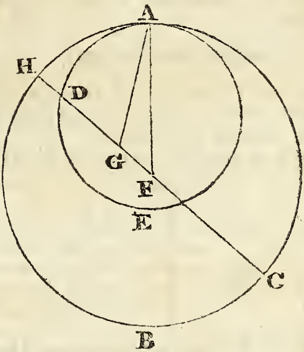


than two points; viz. in B, G, F; take the centre K of the circle A B C, and join KB, K G, K F: and because within the circle D E F there is taken the point K, from which more than two equal straight lines; viz. K B, K G, K F fall on the circumference D E F, the point K is the centre of the circle D E F; but K is also the centre of the circle A B C; therefore the same point is the centre of two circles that cut one another, which is impossible. Therefore one circumference of a circle cannot cut another in more than two points. Q. E. D.

PROPOSITION XI.

THEOREM.—*If two circles touch each other internally, the straight line which joins their centres being produced, will pass through the point of contact.*

Let the two circles A B C, A D E, touch each other internally in the point A, and let F be the centre of the circle A B C, and G the centre of the circle A D E; the straight line which joins the centres F, G, being produced, passes through the point A.



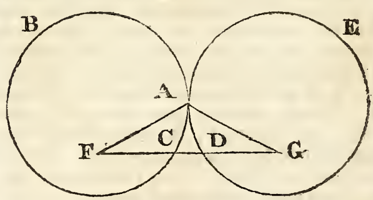
For, if not, let it fall otherwise, if possible, as F G D H, and join AF, A G: And because A G, G F are greater than F A; that is, than F H, for F A is equal to F H being radii of the same circle; take away the common part F G, and the remainder A G is greater than the remainder G H. But A G is equal to G D, therefore G D is greater than G H; and it is also less, which is impossible. Therefore the straight line which joins the points F and and G, cannot fall otherwise than on the point A; that is, it must pass through A. Therefore, if two circles, &c. Q. E. D.

PROPOSITION XII.

THEOREM.—*If two circles touch each other externally, the straight line which joins their centres will pass through the point of contact.*

Let the two circles A B C, A D E touch each other externally in the point A; and let F be the centre of the circle A B C, and G the centre of A D E: The straight line which joins the points F, G shall pass through the point of contact A.

For, if not, let it pass otherwise, if possible, as F C D G, and join F A, A G: and because F is the centre of the circle A B C, A F is equal to F C: Also because

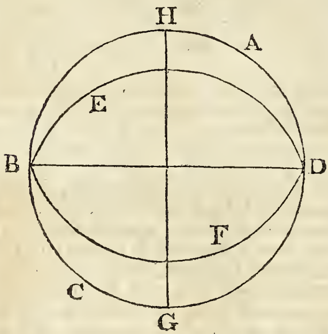


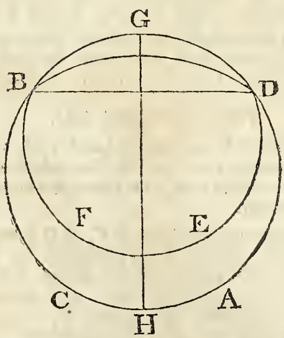
C is the centre of the circle A D E, A G is equal to G D. Therefore F A, A G are equal to F C, D G; wherefore the whole F G is greater than F A, A G; but it is also less, which is impossible: Therefore the straight line which joins the points F, G, cannot pass otherwise than through the point of contact A; that is, it passes through A. Therefore, if two circles, &c. Q. E. D.

PROPOSITION XIII.

THEOREM.—*One circle cannot touch another in more points than one, whether it touches it on the inside or outside.*

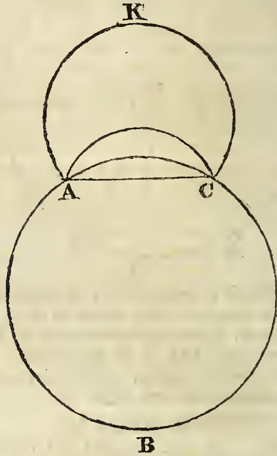
For, if be possible, let the circle E B F





touch the circle A B C in more points than one, and first on the inside, in the points B, D; join B D, and draw G H, bisecting B D at right angles: Therefore, because the points B, D are in the circumference of each of the circles, the straight line B D falls within each of them; and their centres are in the straight line G H, which bisects B D at right angles: Therefore G H passes through the point of contact; but it does not pass through it, because the points B, D are without the straight line G H, which is absurd: Therefore one circle cannot touch another in the inside in more points than one.

Nor can two circles touch one another on the outside in more than one point: For, if it be possible, let the circle A C K touch the circle A B C in the points A, C, and join A C: Therefore, because the two

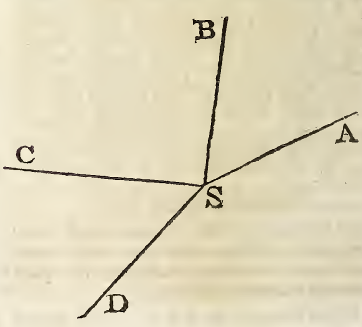


points A, C are in the circumference of the circle A C K, the straight line A C which joins them shall fall within the circle A C K: And the circle A C K is without the circle A B C; and therefore the straight line AC is without this last circle; but, because the points A, C are in the circumference of the circle A B C, the straight line A C must be within the same circle, which is absurd: Therefore a circle cannot touch another on the outside in more than one point; and it has been shown, that a circle cannot touch another on the inside in more than one point. Therefore, one circle, &c. Q. E. D.

MECHANICS.

ROTATION OF BODIES ABOUT A FIXED CENTRE.

If a system of bodies in one plane, as A, B, C, D, &c. in the following figure



be so connected, as to be immoveable with respect to each other, but moveable about an axis at right angles to the plane, and passing through a given point S; and if a force act on one of the bodies A, such, that if A were unconnected with the system, it would receive a different velocity, and move in a direction at right angles to A S: then, if each body be multiplied into the square of its distance from the axis of rotation, the sum of all these products, is to the product of A, into the square of its distance from the same axis, as the velocity which A would have had if it had been free to move by itself, to the velocity which it has as a part of the system.

Hence the momentum of the system relatively to S, is found, by multiplying each body into the square of its distance from S, and the sum into the velocity at A.

These propositions hold not only of a system of bodies in one plane, but of a system in different planes, if we suppose perpendiculars drawn from them to the axis of rotation.

Any system of bodies being given, a point may be found, in which, if all the bodies were collected, a force applied at any distance from the axis would communicate to the bodies, thus collected, the same angular velocity that it would have communicated to the system in its first condition.

The point thus found is called the *Centre of Gyration.*

As every body may be considered as a system of physical points, it is evident that the preceding propositions are of general application.

ROTATION ON A MOVEABLE AXIS.

When the impulse communicated to a body, is in a line passing through its centre of gravity, all the points of the body move forward with the same velocity, and in lines parallel to the direction of the impulse communicated. But when the direction of the impulse communicated does not pass through the centre of gravity, the body acquires a rotation on an axis, and also a progressive motion, by which its centre of gravity is carried forward in the same straight line, and with the same velocity, as if the direction of the impulse had passed through the centre of gravity.

The progressive and rotatory motion are independent of one another, each being the same as if the other had no existence.

This is a consequence of the general law, That the quantity of motion estimated in a given direction, is not affected by the action of the bodies on one another. The revolution of a body on its axis arises from an action of this kind, and can neither increase nor diminish the progressive motion of the whole mass.

The progressive motion if the moving force and the body moved are given, is determined by the principles of Dynamics, see page 21, vol. i, and the rotatory motion is computed, as if it were about a fixed axis, by the propositions just laid down.

When one impulse only is communicated to the body, the axis on which it begins to revolve, is a line drawn through its centre of gravity, and perpendicular to the plane that passes through that centre, and in the direction of the impulse.

When a body revolves on an axis, and a force is impressed, tending to make it revolve on another, it will revolve on neither, but on a line in the same plane with them, dividing the angle which they contain, so that the sines of the parts are in the inverse ratio, of the angular velocities with which the body would have revolved about the said axis, separately.

If a force be impressed on any body, by which it is made to revolve on an axis, the quantity of its momentum, estimated by collecting into one sum all the products of the particles into their velocities, and their distances from the axis of motion, is equal to the momentum of the force impressed, estimated in the same manner.

Hence, though, in consequence of the rotation of a body on its axis, a change may take place in its figure, or in its internal structure, the total quantity of its momentum will continue the same.

A body may begin to revolve on any line as an axis, that passes through its centre of gravity; but it will not continue to revolve permanently about that axis, unless the opposite centrifugal forces exactly balance one another.

A homogeneous sphere may revolve permanently on any diameter, because the opposite parts of the solid, being in every direction equal and similar, the opposite centrifugal forces must be equal; so that no force tends to change the position of the axis.

A homogeneous cylinder may revolve permanently about the line which is its geometric axis. It may also revolve permanently about any line that bisects that axis at right angles; but it can revolve permanently about no other line, as the centrifugal forces cannot be equal. The same is true with respect to all solids of revolution.

In every body, however irregular, there are three axis of permanent rotation, at right angles to one another, on any one of which, when the body revolves, the opposite centrifugal forces exactly balance one another. These are called the principal axis of rotation.

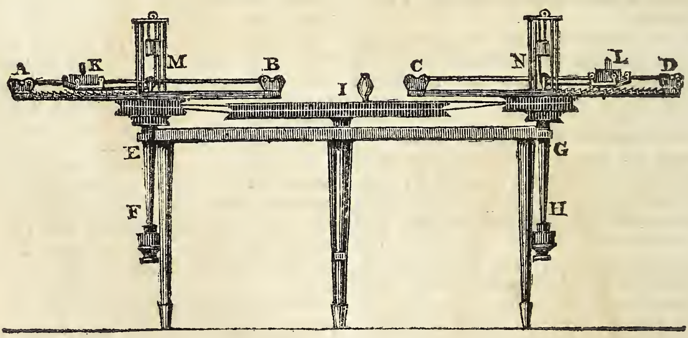
This singular theorem was first proposed by *Segner*, in 1775, and first demonstrated by Albert Euler, in a Memoir, published at Paris in 1760.

These three axes have also this remarkable property, that the momentum of inertia, with respect to any of them, is either a maximum or a minimum; that is, it is either greater or less, than if the body revolved about any other axis. The momentum of inertia has already been defined, to be the product of every particle into the square of its distance from the axis of rotation.

OF THE WHIRLING TABLE.

When a body is retained in a circular orbit, by a force directed to its centre, its velocity is every where equal to that which it would acquire, in falling, by means of the same force, if uniform, through half the radius; that is, through one fourth of the diameter. This proposition affords a very convenient method of comparing the effects of central forces, with those of simple accelerating forces, and deserves to be retained in memory. We may, in some measure, demonstrate its truth, by means of the whirling table: an apparatus, which is constructed for the purpose of exhibiting the properties of central forces, although it is more calculated for showing their comparative, than their absolute magnitude; for accordingly as we place the string on the pullies, the two horizontal arms may be made to revolve, either with equal velocities, or one twice as fast as the other. The sliding stages, which may be placed at different distances from the centres, and which are made to move along the arms with as little friction as possible, are in a certain proportion to the weights which are to be raised, by means of threads passing over pullies in the centres, as soon as the centrifugal forces of the stages with their weights are sufficiently great; and the experiment is to be so arranged, that when the velocity, having been gradually increased, produces a sufficient centrifugal force, both stages may raise their weights, and fly off at the same instant. But for the present purpose, one of the stages only is required, and the time of revolution may be measured by half a second pendulum. We may make the force, or the weight to be raised, equal to the weight of the revolving body; and we shall find that this body will fly off, when its velocity becomes equal to that, which would be acquired by any heavy body, in falling through a height equal to half the distance from the centre, and as much greater, as is sufficient for overcoming the friction of the machine.

The following figure represents a machine of this kind.



The arms A B and C D, are made to revolve on the axis E F and G H, by the string passing over the wheel I, the upper or under pulley of either axis being employed at pleasure; the stages K and L, with their weights, are placed at certain distances from the centre, by means of the racks or teeth below them; they move along the arms by means of friction wheels resting on wires, and they raise the weights M and N, by means of threads passing each over two pullies.

It may also be demonstrated, that when bodies revolve in equal circles, their centrifugal forces are proportional to the squares of their velocities. Thus, in the whirling table, the two stages being equally loaded, one of them, which is made to revolve with twice the velocity of the other, will lift four equal weights, at the same instant that the other raises a single one. But when two bodies revolve with equal velocities at different distances, the forces are inversely as the distances; consequently, the forces are, in all cases, directly as the squares of the velocities, and inversely as the distances.

If two bodies revolve in equal times at different distances, the forces by which they are retained in their orbits, are simply as the distances. If one of the stages of the whirling table be placed at twice the distance of the other, it will raise twice as great a weight, when the revolutions are performed in the same time.

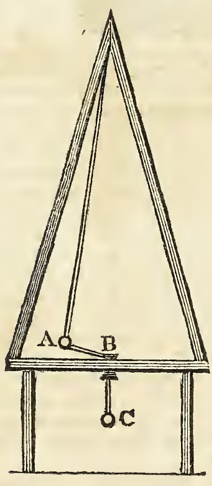
In general, the forces are as the *distances directly*, and as the *squares* of the times of revolution inversely. Thus the same weight revolving in a double time, at the same distance, will have its effect reduced to one fourth; but at a double distance, the effect will again be increased to half of its original magnitude.

From these principles, may be deduced the law discovered by Kepler, in the motions of the planetary bodies, and afterwards demonstrated by Newton from mechanical considerations; but this subject will be fully treated under the head of Astronomy.

We may, however, state here, that another important law, which was discovered by Kepler, may, in some measure, be shown by an experiment on the revolution of a ball, suspended by a long thread, and drawn towards a point, immediately under the point of suspension, by another thread, which may either be held in the hand, or have a weight attached to it.

The law here alluded to is, that the right line joining a revolving body, and its centre of attraction, always describes equal *areas* in equal *times*.

Thus, the ball A, revolving round B,

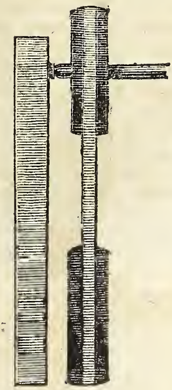


and being drawn towards it by means of the thread B C, with a force variable at pleasure, its velocity may be observed to vary, according to its distance from the point B, which must always be the case; otherwise, the areas described could not be equal, in equal portions of time.

OF WHEEL WORK.

In treating of the simple mechanical power, called the Wheel and Axle, (Vol. i. p. 86), we stated that motion was communicated from one wheel to another, either by belts and straps passing over them, or by teeth cut in the circumference of each, and working in one another. We shall now enter a little more fully into the subject, and endeavour to explain some of the most useful principles, upon which this branch of practical mechanics depends, and also to point out the various methods of applying this mechanical power, in the motion of different kinds of machinery.

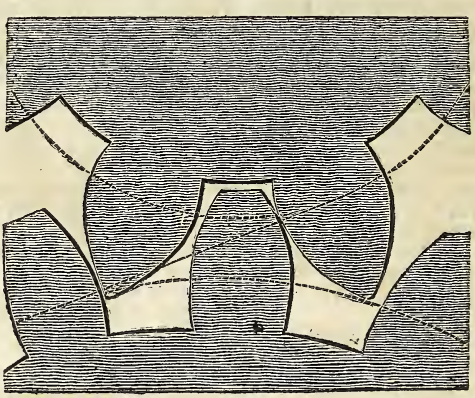
Where a broad strap runs on a wheel, it is usually confined to its situation, not by causing the margin of the wheel to project; but, on the contrary, by making the middle prominent, as represented by the following wheel or pulley, on which



a broad strap runs, the surface being convex; the wheel which drives it is of a similar form; but its upper part only is shown in the figure.

The reason of the middle being made prominent, may be understood, by examining the manner in which a tight strap, running on a cone, would tend to run towards its thickest part. Sometimes also pins are fixed in the wheels, and admitted into perforations in the straps; a mode only practicable, where the motion is slow and steady. A smooth motion may also be obtained, with considerable force, by forming the surfaces of the wheels into brushes of hair. More commonly, however, the circumferences of the contiguous wheels are formed into teeth, impelling each other, as with the extremities of so many levers, either exactly, or nearly in the common direction of the circumferences; and sometimes an endless screw is substituted for one of the wheels.

In forming the teeth of wheels, it is of consequence to determine the curvature which will procure an equable communication of motion, with the least possible friction. For the equable communication of motion, two methods have been recommended; one, that the lower part of the face of each tooth should be a straight line in the direction of the radius, and the upper, a portion of an epicycloid; that is, of a curve described by a point of a circle rolling on the wheel, of which the diameter must be half that of the opposite wheel; and in this case it is demonstrable, that the plane surface of each tooth will act on the curved surface of the opposite tooth, so as to produce an equable angular motion in both wheels: the other method is, to form all the surfaces into portions of the involutes of circles, or the curves described by a point of a thread, which has been wound round the wheel, while it is uncoiled; and this method appears to answer the purpose, in an easier and simpler manner than the former. The following figure represents the teeth, &c. of two wheels, formed into involutes of circles, described by uncoiling a thread from the dotted circles; the point of contact of the teeth being always in the straight line, which touches both circles.



It may be experimentally demonstrated, that an equable motion is produced by the action of these curves on each other; if we cut two boards into forms, terminated by them, divide the surfaces by lines into equal or proportional angular portions, and fix them on any two centres, we shall find, that as they revolve, whatever parts of the surfaces may be in contact, the corresponding lines will always meet each other.

Both of these methods may be derived from the general principle, that the teeth of the one wheel must be of such a form, that their outline may be described by the revolution of a curve upon a given circle, while the outline of the teeth of the other wheel, is described by the same curve revolving within the circle. It has been supposed by some of the best authors, that the epicycloidal tooth, has also the advantage of completely avoiding friction; this is, however, by no means true, and it is even impracticable to invent any form for the teeth of a wheel, which will enable them to act on other teeth without friction. In order to diminish it as much as possible, the teeth must be as small and as numerous, as is consistent with strength and durability; for the effect of friction always increases, with the distance of the point of contact, from the line joining the centres of the wheels. In calculating the quantity of the friction, the velocity with which the parts slide over each other, has generally been taken for its measure: this is a slight inaccuracy of conception, for the actual resistance is not at all increased by increasing the relative velocity; but the effect of that resistance in retarding the motion of the wheels, may be shown from the general laws of mechanics, to be proportional to the relative velocity thus ascertained.

When it is possible to make one wheel act on teeth fixed in the concave surface of another, the friction may be thus diminished in the proportion of the difference of the diameters to their sum.

ELECTRICITY.

The phenomena of electricity are as amusing and popular in their form and appearances, as they are intricate and abstruse in their nature.

In examining these appearances, a philosophical observer will not be content with such exhibitions as dazzle the eye for a moment, without leaving any impression that can be instructive to the mind, but he will be anxious to trace the connection of the facts with their general causes, and to compare them with the theories which have been proposed to account for them; and though the doctrine of electricity is, in many respects, yet in its infancy, we shall find that some hypothesis may be assumed, which are capable of explaining the principal circumstances in a simple and satisfactory manner, and which are extremely useful, in connecting a multitude of detatched facts into an intelligible system. These hypotheses, founded on the discoveries of Franklin, have been gradually formed into a theory, by the investigations of Aepinus, Cavendish, Priestly, Cavallo, combined with the experiments and inferences of Lord Stanhope, Coulomb, Robison, and others.

Some bodies acquire by friction, or rubbing, the power of attracting and repelling certain other bodies. This power is called electricity, and was discovered by the ancients first in *(electrum)* amber.

The effects of this fluid are distinguished from those of all other substances, by an attractive or repulsive quality, which it appears to communicate to different bodies; and which differs in general from other attractions and repulsions, by its immediate diminution or cession, when the bodies, acting on each other, come into contact, or when they are touched by other bodies.

Many substances are possessed of this property; such as glass, sealing wax, agate, and almost all the precious stones.

These bodies attract others, which are very light, as feathers, hairs, &c. The sphere or extent of this attraction is several feet; but it varies with the state of the weather, being greatest in hot dry weather: in warm moist weather, it is very weak. This virtue is excited by rubbing with the hand, or with a piece of cloth; but cannot be produced by the warmth of fire. This virtue exerts itself in vacuo, as well as in air.

If a glass rod be rubbed with the dry hand, or with a piece of silk, in a short time, sparks or flashes of light will dar from its surface, and will attract ligh substances in the same manner as sealing wax. The metals possess none of these properties.

The substances possessing these properties are termed Electrics; and those incapable of being excited, or of producing these effects, *non electrics.*

If an electric be under excitation, and then a non-electric brought near it, or in contact with it, the electricity in the former will be carried off by the latter.

But if an electric be applied in the same manner, to one that has been excited, it will not withdraw the electricity.

From this arises another distinction of bodies into conductors, and non-conductors.

The latter, or non-conductors, being the same as electrics, and conductors the same as non-electrics.

Glass, resinous substances, sulphur, oils, hemp, silk, and the airs or gases, are non-conductors. The principal conductors or non-electrics, are metals, saline and earthy substances, and water.

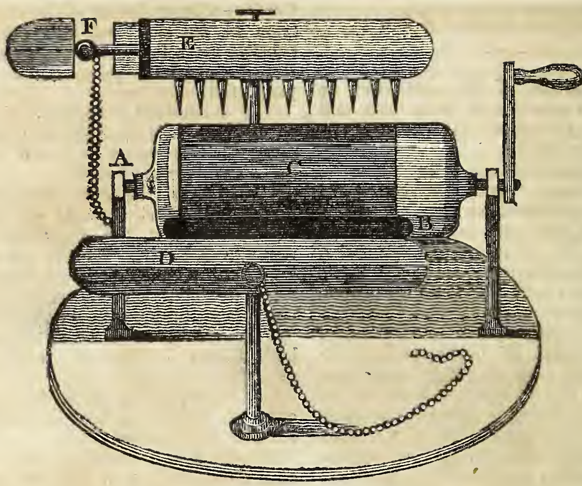
If the electric which is subjected to friction be insulated; that is, supported on another electric, or non-conductor, the quantity of electricity evolved is inconsiderable, and is soon limited. But if a communication of it with the earth be established, by the medium of a conductor, it will afford electricity as long as the friction is continued; and a conductor insulated, if placed before the electric, will receive the electrical power, and retain it till another conductor be applied to it.

On another conductor being applied to it, the accumulated electricity will be instantly carried off, and in this way a stream of electricity can be obtained.

On these principles the common electrical machine is constructed.

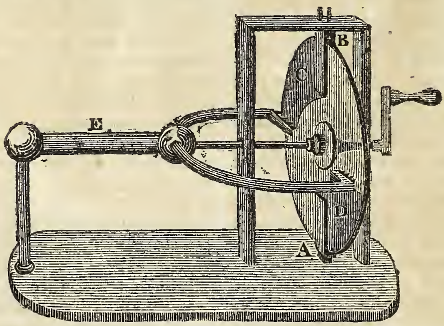
It consists of a glass cylinder, which is made to revolve against a cushion called the rubber, supported on a glass pillar, but connected with the earth by a metal chain; a large metallic tube, containing a number of sharp pointed wires, named the prime conductor, is placed before the cylinder, and insulated, by being supported on a pillar of glass: the electricity is produced by the friction of the cylinder against the cushion or rubber, and is collected by the prime conductor; and on the approach of any conducting substance, instantly passes off under the form of a spark.

The following figure represents an electrical machine on Mr. Nairn's construction.



A is the cylinder of glass; B the cushion or rubber; C the silk flap; D the negative conductor; E the positive conductor; F a ball connected with the internal coating of a glass jar, contained in the conductor. The conductors are insulated by varnished rods of glass.

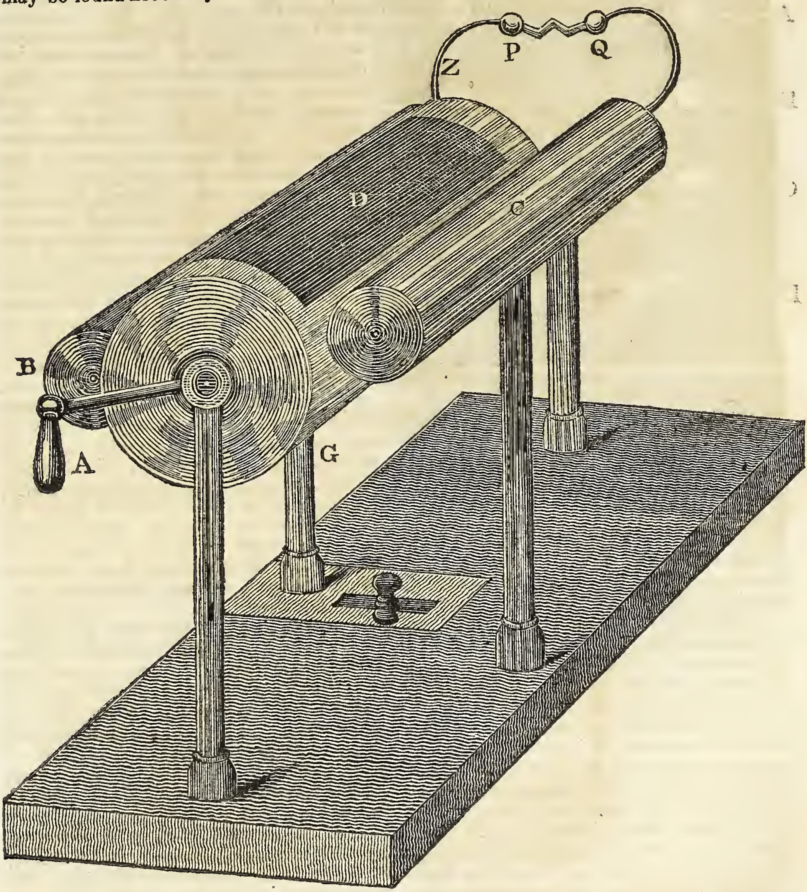
The following figure represents a plate machine.



Here A and B are the rubbers, which are usually double; C D are double flaps of oiled silk, for confining the electricity; and E is the prime conductor.

The most convenient size of an electrical machine, and one that is capable of producing a sufficient quantity of electricity, for exhibiting most of the properties and effects of this wonderful fluid, consists of a cylinder, about eighteen inches long and fourteen in diameter. The two conductors should be of copper or tin, very smooth, round, and without points or edges, except the points which are intended to take off the electricity from the glass cylinder. They should be as long as the cylinder, and about eight or nine inches in diameter. The cushion, which is fixed to the negative conductor, should be of red leather, about ten inches long, and stuffed evenly with curled hair. It should be fixed, so as to lie flat to the cylinder; and on its under side must be sewed a piece of the above leather, ten inches wide, and five inches long; and at the same place a piece of black silk, about ten inches wide and sixteen long, to reach nearly over the cylinder to the prime conductor. A row of points, eight or ten in number, must project from the prime conductor, each about the length of common pins, whose points must be as near the glass cylinder as possible, without touching it: both ends of the cylinder, as well as the two conductors, must be supported on solid glass pillars, as already stated. The pillar which supports the cushion or rubber, should be fastened on a piece of board that should slide in a groove, and be fixed by a wooden screw to the board that supports the whole machine; this is to press the cushion more or less to the cylinder, as may be found necessary.

The following figure represents a machine of the form and construction here recommended.



The letter A is the handle for turning the machine; C is the prime conductor; B the negative conductor; and D the cylinder.

Electricity then, is excited by the friction of an electric; but different electric, and even the same electric under different circumstances, exhibits different appearances under a state of excitation, and this gives rise to the important distinction of two forms of electricity, named positive and negative.

If a glass rod be excited by friction with a woollen cloth, it will attract light substances, as, a bit of cork; the cork is first attracted, but in a short time it is repelled, and is not again attracted until it has touched some conducting substance.

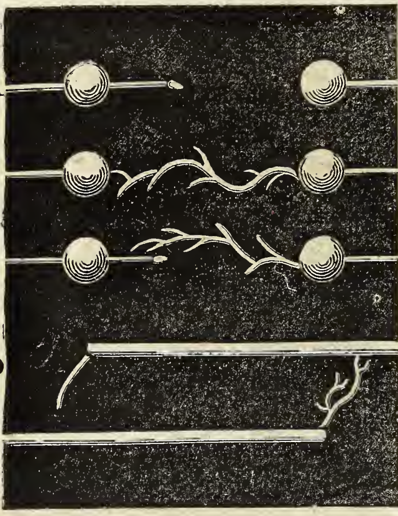
But if a rod of sealing-wax has been excited by friction, with the cloth, the cork, in the state in which it is repelled by the glass, is attracted by the wax, and *vice versa*.

These electrics also present the electric *light* under different forms.

The appearance of the electrical light of a point enables us to distinguish the nature of the electricity with which it is charged; a pencil of light, streaming from the point, indicating that its electricity is positive, while a luminous star, with a few diverging rays, shews that it is negative.

The sparks exhibited by small balls, differently electrified, have also similar varieties in their forms according to the nature of their charges. These appearances are well represented by the following figure:

A
B
C
D



Here A is a spark passing between a negative and a neutral ball; B, between a neutral and positive ball; C, between a negative and a positive ball. D, two sparks between a negative and a positive cylinder, each of the same form as if it were passing singly from the end of a charged to the side of a neutral cylinder.

If a pointed conductor, as a needle, be presented to the glass, a round lucid point appears on its extremity in the dark; but if presented to the wax, a pencil of rays seems to issue from the needle.

And if two bodies in these two different states be brought into contact, or be made to communicate by means of a conductor, the electricity in the one appears to neutralize that in the other, and the electrical appearances cease. The one of these electricities being *first* obtained from glass, was named vitreous, and the other from resinous bodies, such as wax, amber, &c. was named resinous electricity:—and were regarded as different. It was discovered however, that when two electrics are rubbed against each other, the one always acquires the one electricity, and the other the other. Thus, in the common electrical machine, when the cushion is insulated, on friction being produced, it exhibits what has been named the *resinous* electricity, while the glass yields the *vitreous*; and by certain management the same electric may be made to exhibit *either* electricity, glass the resinous, and sulphur or sealing-wax the vitreous.*

From these facts Dr. Franklin was led to deny that there was two different kinds of electricity; and stated that there exists only one agent by which they are produced. To the two varieties just stated, he gave the names of plus and minus, or positive and negative. The vitreous he called *positive*, and the resinous he called *negative* electricity. This division accounted so well for the discharge of the Leyden phial, that electricians have, in general, preferred it, on account of its simplicity. These two electricities therefore are regarded as the opposite of each other; and when the equilibrium of these forces is destroyed, the electric fluid is put in motion; those bodies which allow the fluids a free passage, are called perfect conductors; but those which impede its motion, more or less, are imperfect conductors For example: while the electric fluid is received into the metallic cylinder of the electrical machine, its accumulation may be prevented, by the application of the hand to the cylinder which receives it, and it will pass off through the person of the operator to the ground; hence the human body is called a conductor. But when the metallic cylinder, or prime conductor, of the machine is surrounded only by dry air, and supported by glass, the electric fluid is retained, and its density increased, until it becomes capable of procuring itself a passage some inches in length, through the air, which is a very imperfect conductor.

If a person connected with the prime conductor, be placed on a stool with glass legs, the electricity will no longer pass through him to the earth, but may be so accumulated as to make its way to any neighbouring substance which is capable of receiving it, exhibiting a luminous appearance, called a spark; and a person, or any other substance, so placed as to be in contact with non-conductors only, is said to be insulated. When electricity is abstracted from substances thus insulated, it is said to be negatively electrified, but the sensible effects are nearly the same, except that in some cases the form of the spark is a little different, as already observed above.

Perfect conductors, when electrified, are in general either overcharged or undercharged with electricity in their most distant parts at the same time; but non-conductors, although they have an equal attraction for the electric fluid, are often differently affected in different parts of their substances; even when those parts are similarly situated in every respect, except that some of them have had their electricity increased or diminished by a foreign cause. This property of non-conductors may be illustrated by means of a cake of resin, or a plate of glass, to which a local electricity may be communicated in any part of its surface, by the

* This is by using a rubber of a different substance.

contact of an electrified body; and the parts, thus electrified, may afterwards be distinguished from the rest, by the attraction which they exert on a small particles of dust or powder projected near them: the manner in which the particles arrange themselves on the surface, indicating also, in some cases, the species of electricity, whether positive or negative, that has been employed; positive electricity producing an appearance somewhat resembling feathers; and negative electricity an arangement more like spots. The inequality in the distribution of the electric fluid in a non-conductor may remain for some hours, or even some days, continually diminishing, till it becomes imperceptible.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF BLAISE PASCAL.

Blaise Pascal was born at Clermont, in Auvergne, on the 19th of June, 1623. Etienne Pascal, the father, was first president of the *Cour-des-aides* in Clermont, and discharged the duties of his office with a probity and discretion analogous to the calm and amiable virtues of his private character.

His son Blaise, discovered from his earliest years a purity of disposition and a power of understanding calculated to satisfy the fondest parent. Gifted with a retentive memory and a surprising acuteness of apprehension, he made rapid progress in every species of polite literature to which his faculties were applied. The aptitude he showed for the exact sciences was still more wonderful. The attention of thinking men was now awakened to those subjects by the discoveries of Galileo, which had already begun to operate the changes so sensibly felt before the century was concluded. Roberval, Carcavi, with a number of other scientific men at Paris, among whom was Etienne Pascal, had formed themselves into a kind of society for discussing such matters; they met at each other's houses, subject to no law but the pleasure they felt in usefully communicating their discoveries or information; a pleasure which they continued to enjoy in this natural and simple form, till a royal charter (in 1656) converted this friendly club into the *Academie des Sciences*.

Young Pascal listened with a boundless curiosity to what passed when the meeting was held at his father's. The conversation excited all his energies towards an object fitted for his intellect, and recommended to his imagination by the esteem it gained from all whose opinion he honoured most highly. A *Treatise on Sound*, written at the age of eleven, might have gratified his father's partiality, had it not been feared that so ardent a devotion to mathematics might cut off the hope of progress in other branches of learning more suited to his age and capacity. Blaise was therefore enjoined to attend exclusively to language, as a pursuit more profitable in its consequences, and better fitted for one of his years; while, in order to sweeten the disappointment, an assurance was given, that if once Greek were mastered, he should be allowed immediately to begin geometry, concerning which it was enough for him at present to know that its object lay in examining the properties of figures, and pointing out the various relations that subsist among their several dimensions. But the proffered hope was too distant for soothing the boy's impatience, which this vague and general description now served to direct and inflame. Blaise spent his play-hours by himself in a remote room; he traced a variety of circles, triangles, and squares, on the floor, with a piece of charcoal; he arranged and combined them as fancy or judgment prompted; and, without the help of an instructor, of definitions, or even of language, he is said to have actually discovered the truth of Euclid's thirty-second proposition, that all the angles of any triangle are measured by arcs, which together amount to a semicircumference. His father detected the circumstance, and consented with tears of joy no longer to withstand the cultivation of a talent, which his son had shown so decided a disposition and so extraordinary a power to improve. The study of mathematics, commenced under such auspices, was carried on with a corresponding success. The young man read Euclid by his own exertions without difficulty at the age of twelve; and, four years after, he composed what was then considered an admirable treatise on Conic Sections. But his efforts were soon directed to higher objects than learning, or even improving, what others had discovered. Enjoying the singular advantage of being permitted to give himself up without reserve to the prosecution of science, his ardent mind advanced with gigantic steps in this career. He profited by intercourse with the society which had originally kindled his enthusiasm, and soon repaid them by investigations of his own.

In 1641, a change in his father's circumstances caused young Pascal to change his residence to Rouen, where he soon distinguished himself by the invention of his famous *arithmetical machine*. The present is not a fit place for describing this curious contrivance: its object was, to perform the operations of multiplying and dividing by a combination of cylinders, marked with certain columns of numbers, and turned by wheel-work. The object was gained, theoretically speaking; but the complexity of the instrument, and the facilities attached to the use of logarithms, rendered it inapplicable to practical purposes.—Like the simpler calculating machine of Leibnitz, it remains a wonderful but useless proof of its author's ingenuity.

Pascal's inventive powers were not long after exhibited in a way as striking, and far more beneficial to the cause of knowledge. We need not detail the circumstances which led Galileo to doubt the truth of Nature's abhorring a vacuum, or Torricelli to maintain, that the ascent of water in the sucking pump, or of mercury in a glass tube free of air, is due to the unbalanced weight of an atmospheric column pressing on the external fluid. Torricelli died in 1646, before the truth of his conclusion could be firmly established. The experiments, but not the inference, were casually reported to Pascal, who repeated them with important variations, and asserted the same opinion in a small work published next year, under the title of *Expériences nouvelles touchant le vuide.* Yet the victory was not tamely yielded. A subtle matter, aerian spirits, every argument or hypothesis which the bad philosophy of the time could furnish, was employed to support the falling *horror of a vacuum*; the Jesuit Noel had published his objections, when Pascal was lucky enough to devise an experiment which set the matter completely at rest. If the mercury were suspended by the weight of the superincumbent atmosphere, it was evident that the quantity suspended must diminish, as the weight, and consequently as the height, of that atmosphere diminished; hence, if Torricelli's view of the subject were correct, the fluid must sink as it approached a higher level and carried less air above it: if the mercury were not so suspended, or if the atmosphere were destitute of weight, no such effect would follow; and at the top of the highest elevation, the fluid would rise 29 inches above its external level, exactly as it did at the bottom. Pascal fixed upon his native mountain, the Puy-de-Dome, for exemplifying those reasonings; and being confined by ill health, he committed the execution of the project to M. Perier, his brother-in-law. It was performed on the 19th of September, 1648; the mercury rose and fell as he had predicted; the gravity of the air was proved, and Aristotle's maxim destroyed for ever.

Pascal's name is indelibly impressed on the history of the barometer; it is also closely united with many of the most important mathematical and physical inquiries, which during the next age occupied the attention of scientific men. From considering a particular case, he was easily led to investigate the general problem relating to the equilibrium of fluids; his principle demonstrated in two different ways, and the curious details which accompany it, were published after his death, in the *Traité sur l'equilibre des liqueurs*, and the *Traité sur la pésanteur de la masse de l'air.* The solution of two questions proposed by an ignorant gamester, the Count de Meré, laid a foundation for the modern doctrine of probabilities: his various geometrical tracts are unfortunately lost; but enough is known of his *Arithmetical triangle* to show, that if his purusits had been continued, the author of so beautiful an invention might have anticipated some of the most brilliant discoveries of a subsequent age.

But the incessant application which produced results of such variety and extent, produced another consequence equally inevitable, the loss of health, with all its attendant evils. From his 19th year, Pascal had laboured under the effects of excessive study; in 1647, he was seized with a paralysis, which for three months almost entirely took away the use of his limbs. The family now returned to Paris, and forced him in some degree to relax his efforts.

One day in the month of October, 1654, having gone out as usual to take the air in a carriage, he was proceeding over the Seine by the bridge of Neuilly, when the two foremost horses taking fright at a spot where the parapet was wanting, rushed furiously onward and plunged headlong into the river. Providentially their traces gave way; the hindmost pair stood shuddering on the verge, and were led back unhurt. But the shock which such an awful occurrence must have communicated to the feeble frame of Pascal, may easily be conceived. He recovered with difficulty from a long swoon; the precipice was for weeks continually present to his imagination; it haunted his dreams, and occasioned waking visions, one of which, in particular, made such an impression, that he wrote an account of it, and wore the paper ever after between the cloth and the lining of his coat. By degrees, however, these alarming effects subsided; they were followed by others of a milder but more permanent nature. He determined to employ his remaining days in religious meditation. The example of his sister Jacqueline gave strength to this resolution, and perhaps invited him to Port-Royal in fulfilment of it. Here, in the company of Arnaud, Saci, Nicole, and a few others of similar habits, he spent most of his time;

not indeed as a member of the establishment, but as a visitor, whose stay was sometimes lengthened to many months.

In this retreat, endeared by the sanctity of its object, and enlivened by the society of men imbued with kindred opinions, Pascal gradually recovered some tranquillity; he enjoyed intervals of comparative health, during which fresh triumphs in a new department gave farther proof of the compass and versatility of his powers.

His thoughts had long flowed exclusively in the channel of devotion, and present circumstances naturally contributed to strengthen this tendency. Yet, before his course was done, the speculations of early life resumed their sway on one occasion with a force and effect, which showed that his mathematical powers were diverted, not destroyed. It was in 1658, when an excruciating tooth-ache had kept him long deprived of sleep, that he happened to recollect some properties formerly discovered by him respecting the cycloid; and their beauty was such, that, to procure some abstraction from his suffering, he determined to investigate their consequences. The results which he obtained, without the aid of modern analysis, are still reckoned by mathematicians among the finest exhibitions of their art. Pascal was advised to publish them by way of challenge, to show that the highest attainments in a science of strict reasoning were not incompatible with the humblest belief in the principles of religion. His problems were accordingly announced under the assumed name of Amos Dettonville; and a premium of forty pistoles was promised to whoever solved them first, of twenty to whoever solved them next. The competition, though graced by some of the first names in Europe, was not successful to any. Our countrymen, Wallis and Wren, were among the number; and the former having failed of success by incorrectness of execution, rather than by error of principle, accused Dettonville of injustice in not assigning him the prize. A similar complaint was made, with far less reason, and the very worst success, by the Père Lallouire, a Jesuit; and Pascal, to defend himself from such insinuations, soon published his treatise on the cycloid, containing the complete solution, which none of the claimants had succeeded in finding.

The character of Pascal, considered as a moral or as an intellectual man, affords a bright though unequal specimen of human nature. Uniting a saint-like purity and tenderness of heart, with an understanding at once fine and capacious, his short existence was marked by the practice of benevolence and self-denial, no less than by a series of brilliant discoveries in the highest regions of philosophy. Though he lived but thirty-nine years, the longer, and what is more important, the latter part of which was spent in almost continual ill-health; yet such was the excellence of his powers, and such the enthusiasm which impelled them, that Pascal's name is found conspicuously engraven on all the most important scientific achievements of his time; while, in the nobler parts of literature, he occupies a rank which few of his countrymen have aimed at, and still fewer reached.

METHOD OF SOFTENING STEEL.

It is well known that steel acquires hardness from tempering only in proportion as it has been heated red-hot before its immersion in water; but many persons are not aware, *that steel, heated a little above the degree necessary to temper it, becomes soft by that very operation of tempering*, and that this process, for nealing it, is much superior to the ordinary methods, since the metal is worked much more easily with the file or burin, and is without flaws or rough edges. This process in no way deteriorates it, and it considerably abridges the operation. Common springs are tempered and nealed by two distinct operations: first, they are heated to the degree requisite, and then dipped in water or oil, &c., and afterwards softened or nealed by heating them by degrees, till their surface when well cleaned, presents a series of colours announcing different degrees of hardness lost. Sometimes the nealing is performed by burning upon the spring the oil in which it has previously been tempered. These two operations can be effected at once, in the following manner.

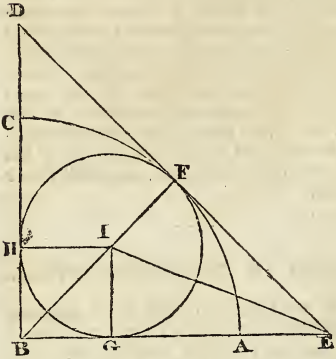
To heat the steel to the degree required, it must be plunged in a metallic bath, composed of a mixture of lead and tin, resembling very nearly the solder used by pump-makers. This mixture is heated to the degree required for tempering, by a stove, in which it is placed in a vessel of cast iron; there is in this bath a pyrometer, to indicate the temperature. Thus the steel is at once tempered and nealed, without any danger of its bending or cracking in the process.

It would be advisable to heat the steel to be tempered in a red-hot bath of lead, before tempering it in the second metallic bath intended for nealing it. It would thus be heated more uniformly, and be less exposed to oxidation.—*(Ann. de la Soc. d' Agr.)*

SOLUTIONS OF QUESTIONS.

QUEST. 52, *answered by* G. G. C.

CON. Let A B C be the given quadrant;



bisect the angle A B C by the straight line B F, and at the point F draw the indefinite line D E, at right angles to B F; produce B A and B C to meet E D in the points D and E; bisect the angle B E D, by the straight line E I, then with the centre I and radius I F, describe the circle F G H, which is the circle required.

DEMON. Join I F, I G, and I H, and because they are radii of the circle they are all equal; and because D E is at right angles to the diameter B F, it touches the circle in that point. But the triangles E F I and E G I are equal, for the two sides F I and I E, are equal to the two G I and I E, and the angle F E I is equal to G E I, hence the angle E G I is equal to E F I; but E F I is a right angle, hence E G I is also a right angle; therefore E B touches the circle in the point G. In the same manner it may be shown, that the angle I H B is equal to I G B, which is also a right angle, hence the line B D touches the circle in the point H; therefore a circle has been inscribed in the given quadrant A B C.

The demonstration of this problem might have been effected differently, by drawing the lines I F, I G, and I H at right angles to the sides of the triangle upon which they fall, and then proving that they are all equal to each other, in which case, a circle described from the centre I. with any of them as a radius, would pass through the points F G H; therefore the lines B D, B E, and E D, touch the circle in these points.

The Proposer sent us a solution to this question; but though the construction was good, the demonstration was not so: for all that he attempts to prove is, that *two radii* (as I F and I G) are equal. Now it is necessary to show, that *three* lines, going from the centre to the circumference, are equal; and that the srtaight lines at their extremities, *touch the circle.*

The Proposer's demonstration would have been inadmissible, had it even been conclusive; for the first part of it is *geometrcal* and the latter *algebraical.*

Now Geometry and Algebra are quite distinct branches of the Mathematics; and therefore Algebra must be completely excluded from a geometrical demonstration, which was the species of proof required in this problem, as the Proposer must surely know!

We received another solution; but the construction was too complex, and it was unaccompanied by any thing like *demonstration.* ED.

QUESTIONS FOR SOLUTION.

QUEST. 56, *proposed by* D. T. *Cheapside.*

A grazier has 50 calves, value 21*s.* each; if he keep them 3 years, they will cost 10*s.* the first year, 20*s.* the second, and 30*s.* the third, for Summer's grass; and 15*s.* the first year, 25*s.* the second, and 40*s.* the third, for Winter feeding, after which the cattle will sell at 10 guineas each. Required his gain or loss by bringing them up, supposing one to die each Summer, another each Winter, and allowing simple interest from the end of each year?

QUEST. 57, *proposed by* G. G. C. *Queen-street.*

A and B jointly perform a piece of work in 12 days; and if the sum of the days in which they could each have separately done the work, be multiplied by the days in which A alone could have done it, the product will be 1000. Required the time in which each can do it?

QUEST. 58, *proposed by* J. D. *Ironmonger Lane.*

If a cubic foot of brass were drawn out into wire, $\frac{1}{40}$th of an inch diameter; required the length of the wire, supposing no loss of the metal?

PNEUMATICS.

RESISTANCE OF THE AIR.

The resistance of fluids has long been an important subject of consideration with philosophers. The subject is highly interesting, not as serving to show the absurdity of exploded theories, but to explain the movements of bodies propelled through the air.

The term "resistance," in regard to retarded motions, is of similar import with the expression "moving force," as applied to accelerated motions. The moving force is estimated by the product of the "tendency" of each particle in a mass, into the number of particles which it may contain, and is synonymous with the word *weight* in common language. Resistance to a body is measured by its loss of momentum, or is equal to the product of the retardation of each particle into the number of particles. Thus, a body descending *in vacuo*, its *weight* is the *moving force;* but to an ascending body, its weight is the resistance.

To a body ascending or descending perpendicularly through the air, there is a degree of velocity, such, that the retardation consequent upon it, is equal to the accellerating force of gravity. It is, therefore, obvious, that when a descending body has once acquired this velocity, it can acquire no increase of velocity in its future descent, as the retardation and acceleration are equal; hence it has been called the *terminal* velocity.

For an iron ball of 1 pound, the terminal velocity has been found to be 244 feet; for one of 42 pounds, it is 456 feet.

In strictness, this velocity cannot be acquired till after an infinite time, and a descent infinitely long; but the time of acquiring any given velocity can easily be assigned. This will be shown in another part of this work.

The resistance of the air is often many times the weight of a body moving in it. An iron ball, for example, 3 pounds in weight, whose diameter is 2·8 inches, when thrown with a velocity of 1800 feet per second, is resisted by a force equal to 176 pounds, which is more than 58 times its own weight.

The resistance of the air, like every other arrangement of Nature, points out to us the beneficent character, and unerring wisdom of its Creator. He has formed it of such a density, as is the best possible for supporting animal existence, and at the same time for supplying a due quantity of moisture to the vegetable creation. Had the air been much less dense than it is, the drops of rain would descend with such a velocity, as would completely destroy that delicate organization, which they are designed to refresh. The earth would no longer grow green under the influence of the summer showers, but would be converted into a barren waste, where the most hardy plants could not flourish. As at present constituted, even the heaviest drops of rain are so much retarded in their descent, that they do not injure the tenderest shoot.

It has been determined by calculation, that the terminal velocity of a drop of rain, whose diameter is $\frac{1}{10}$th of an inch, is 10·48 feet.

Now, were there no atmosphere, and this particle to drop from the same height as at present, its momentum would be incomparably greater, and could be sustained by no object without the greatest injury.

AIR AS THE VEHICLE OF SOUND.

One of the most remarkable properties of air in motion, is its capacity for transmitting sound. The variety and delicacy of the sensations, which are acquired through this medium, are no less admirable, than the wise and beautiful arrangement by which they are communicated. The first who apppears to have considered this subject in a philosophical point of view, was the illustrious Newton, who explained with very great precision the nature of the phenomenon. The continental writers, though they admit his conclusions, have called in question the accuracy of his demonstration. Euler, La Grange, and several others, have engaged in the subject, but have added nothing new to our information; for they have been under the necessity of restricting themselves to the cases which Newton has supposed. We shall therefore state them in a more detailed manner, than that in which they are delivered in the *Principia*. Sound is produced by a sudden condensation of air, which gradually extends itself in the form of a pulse, or spherical shell, having its density greater than that of the surrounding medium. The first proposition delivered by Newton, concerning these pulses is, that the particles of which they are composed, advance from and recede to their state of quiescence, under the influence of a force, which varies as their distance from the point of greatest condensation. He assumes, however, in his reasoning, that the greatest condensation differs only by a very small quantity, from the condensation of common air; an assumption which will be found agreeable to fact, except perhaps in the case of violent explosions, where the condensation of the adjacent particles will be considerably greater.

Sound is a motion capable of affecting the ear with the sensation peculiar to that organ. It is not simply a vibration or undulation of the air, as it is sometimes called; for there are many sounds in which the air is not concerned, as when a tuning fork, or any other sounding body, is held by the teeth: nor is sound always a vibration, or alternation of any kind; for every noise is a sound, and a noise, as distinguished from a continued sound, consists of a single impulse in one direction only, sometimes without any alternation; while a continued sound is a succession of such impulses, which, in the organ of hearing at least, cannot but be alternate. If these successive impulses form a connected series, following each other too rapidly to be separately distinguished, they constitute a continued sound, like that of the voice in speaking; and if they are equal among themselves in duration, they produce a musical or equable sound, as that of a vibrating chord or string, or of the voice in singing. Thus, a quill striking against a piece of wood causes a noise, but against the teeth of a wheel or of a comb, a continued sound; and if the teeth of the wheel are at equal distances, and the velocity of the motion is constant, a musical note is produced.

Sounds of all kinds are most usually conveyed through the medium of the air; and the necessity of the presence of this, or of some other material substance, for its transmission is easily shown by means of the air pump; for the sound of a bell struck in an exhausted receiver, is scarcely perceptible. The experiment is most conveniently performed in a moveable receiver or transferrer, which may be shaken at pleasure, the frame which suspends the bell being supported by some very soft substance, such as cork or wool. As the air is gradually admitted, the sound becomes stronger and stronger, although it is still much weakened by the interposition of the glass: not that glass is in itself a bad conductor of sound; but the change of the medium of communication from air to glass, and again from glass to air, occasions a great diminution of its intensity. It is perhaps on account of the apparent facility with which sound is transmitted by air, that the doctrine of acoustics has been usually considered as immediately dependant on pneumatics, although it belongs as much to the theory of the mechanics of solid bodies, as to that of hydrodynamics.

A certain time is always required for the transmission of an impulse through a material substance, even through such substances, as appear to be the hardest and the least compressible. It is demonstrable, that all minute impulses are conveyed through any homogeneous elastic medium, whether solid or fluid, with a uniform velocity, which is always equal to that which a heavy body would acquire, by falling through half the height of the atmosphere, supposed to be of equal density; so that the velocity of sound passing through an atmosphere of a uniform elastic fluid, must be the same with that of a wave moving on its surface. In order to form a distinct idea of the manner in which sound is propagated through an elastic substance like air, we must first consider the motion of a single particle, which, in the case of a noise, is pushed forwards, and then either remains stationary, or returns back to its original situation; but in the case of a musical sound, is continually moved backwards and forwards, with a velocity always varying, and varying by different degrees, according to the nature or quality of the tone; for instance, differently in the notes of a bell and of a trumpet. We may first suppose, for the sake of simplicity, a single series of particles, to be placed only in the same line with the direction of the motion. It is obvious, that if these particles were sbsolutely incompressible, or infinitely elastic, and were also retained in contact with each other, by an infinite force of cohesion or of compression, the whole series must move precisely at the same time, as well as in the same manner. But in a substance, which is both compressible and extensible, or expansible, the motion must occupy a certain time, in being propagated to the successive particles on either side, by means of the impulse of the first particle on those which are before it, and by means of the diminution of its pressure on those which are behind; so that when the sound consists of a series of alternations, the motion of some of the particles will be always in a less advanced state, than that of others nearer to its source; while at a greater distance forwards, the particles will be in the opposite stage of the undulation; and still further on, they will again be moving in the same manner with the first particle, in consequence of the effect of a former vibration.

The situation of a particle at any time, may be represented by supposing it to mark its path, on a surface sliding uniformly along in a transverse direction. Thus, if we fix a small pencil in a vibrating rod, and draw a sheet of paper along, against the point of the pencil, an undulated line will be marked on the paper, and will correctly represent the progress of the vibration. Whatever the nature of the sound transmitted through any medium may be, it may be shown that the path thus described will also indicate the situation of the different particles at any one time. The simplest case of the motion of the particles, is that in which they observe the same law with the vibration of a pendulum, which is always found opposite to a point, supposed to move uniformly in a circle: in this case the path described will be the figure denominated a harmonic curve; and it may be demonstrated, that the force impelling any particle backwards or forwards, will always be represented, by the distance of the particle before or behind its natural place; the greatest condensation and the greatest direct velocity, as well as the greatest rarefaction and retrograde velocity, happening at the instant when it passes through its natural place.

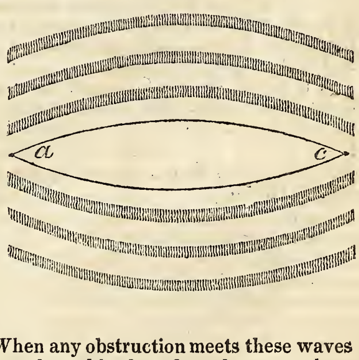
The least elastic substance that has been examined, is perhaps carbonic acid gas, or fixed air, which is considerably denser than atmospheric air exposed to an equal degree of pressure. The height of the atmosphere, supposed to be homogeneous, is in ordinary circumstances, and at the sea side, about 28,000 feet, and in falling through half this height, a heavy body would acquire a velocity of 946 feet in a second. But from a comparison of the accurate experiments of Derham, made in the day time, with those of the French Academicians, made chiefly at night, it appears that the true velocity of sound is about 1130 feet in a second, which agrees very nearly with some observations, made with great care, by Professor Pictet. This difference betweeu calculation and experiment, has long occupied the attention of natural philosophers; but the difficulty appears to have been in a great measure removed, by the happy suggestion of Laplace, who has attributed the effect to the elevation of temperature, which is always found to accompany the action of condensation, and to the depression produced by rarefaction.

This velocity remains unchanged by any alternation of pressure, indicated by the barometer; but it may be affected by a change of temperature.

The Academicians del Cimento, enclosed an organ pipe, with bellows worked by a spring, in the receiver of an air pump and of a condenser; and they found that, as long as the sound was audible, its pitch remained unchanged. Papin screwed a whistle on the orifice, which admits the air into the receiver of the air pump; and Dr. Young fixed an organ pipe in the same manner, and the result agreed with the experiments of the Academicians. But if the density of the air is changed, while its elasticity remains unaltered, which happens when it is expanded by heat, or condensed by cold, the height of the column, and consequently the velocity, will also be altered; so that for each degree of Fahrenheit's thermometer, the velocity will vary about one part in a thousand.

It does not appear that any direct experiments have been made, on the velocity with which an impulse is transmitted through a liquid, although it is well known that liquids are capable of conveying sound without difficulty: Professor Robinson informs us, for example, that he heard the sound of a bell transmitted by water 1200 feet. It is, however, easy to calculate the velocity with which sound must be propagated in any liquid, of which the compressibility has been measured. Mr. Canton has ascertained, that the elasticity of water is about 22,000 times as great as that of air; it is, therefore, measured by the height of a column, which is in the same proportion to 34 feet; that is, 750 thousand feet, and the velocity corresponding to half this height, is 4900 feet in a second. In mercury, also, it appears from Mr. Canton's experiments, that the velocity must be nearly the same as in water, in spirit of wine a little smaller.

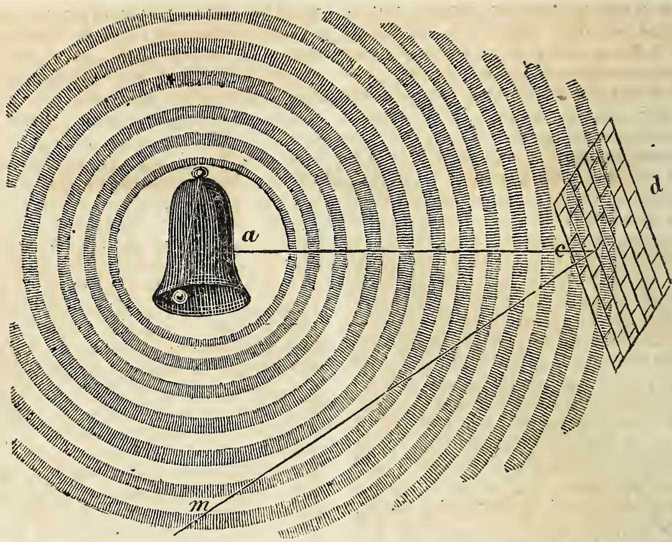
We have hitherto considered the propagation of sound in a single right line, or in parallel lines only; but it usually happens, at least when a sound is transmitted through a fluid, that the impulse spreads in every direction, like a wave, so as to occupy at any one time nearly the whole of a spherical surface, as represented by the following figure.



When any obstruction meets these waves they rebound back and produce an echo.

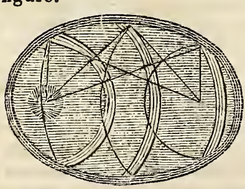
When the waves strike obliquely upon a reflecting surface, the echo may then be heard, but not the original sound.

Thus, if a wave as *a c* in the following figure,

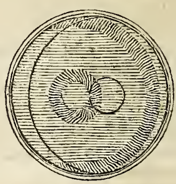


strike against the oblique wall *d*, the sound will be reflected to an ear at *m*; and if a hill should intervene between the bell at *a*, and the ear at *m*, then will the echo be heard at *m*, and not the original sound of the bell. We must, however, remark, that it is necessary the reflecting object be at a distance moderately great, otherwise the returning sound will be confused with the original one; and it must either have a smooth surface, or consist of a number of surfaces, arranged in a suitable form; thus there is an echo, not only from a distant wall or rock, but frequently from the trees in a wood, and sometimes, as it it is said, even from a cloud.

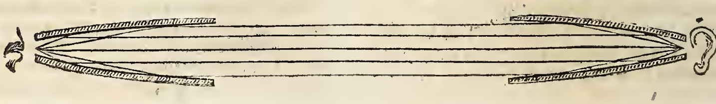
If a sound or wave proceed from one focus of an ellipsis, and be reflected at its circumference, it will be directed from every part of the circumference towards the other focus, as represented by the following figure.



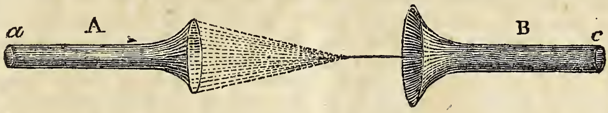
The truth of this proposition may be easily shown, by means of the apparatus already described, for exhibiting the motions of the waves of water; we may also confirm it by a simple experiment on a dish of tea: the curvature of a circle differs so little from that of an ellipsis of small eccentricity, that if we let a drop fall into the cup near its centre, the little wave which is excited will be made to converge to a point at an equal distance on the other side of the centre, see the annexed figure.



Sound is capable of being condensed in a tube, or speaking trumpet, so as to penetrate through the air to a great distance, in one line. For all the waves that fly off globularly from a sounding body, are by this trumpet condensed into one line, and, therefore, its force becomes greater than when left at liberty. The annexed figure represents a section of a speaking trumpet, and also of a hearing one; the lines representing the direction of the sound before and after its reflections. The trumpet has

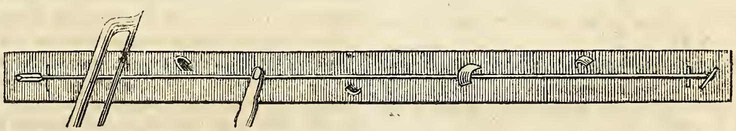


the effect of reflecting the waves, both in receiving and delivering sound; for waves striking the mouth of the trumpet, B, from without, become condensed in the tube, and strike an ear at *c* with the compressed force of all the waves that cover the mouth of the trumpet: hence its effect in assisting deafness. If two trumpets, as A and B, be placed in the axis of each other, as in the annexed figure, at forty or fifty feet distance,

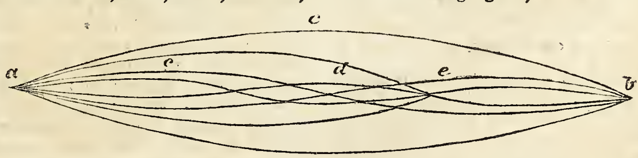


the smallest whisper at *a* would be heard distinctly by an ear placed at *c*; and *vice versâ:* so that a person might ask a question at *a*, and receive an answer from *c*. The answers seemingly given by inanimate figures, is a trick founded on this principle.

In the case of a vibration, it is found that every chord vibrates in the same manner, as if it were a part of a longer chord, composed of any number of such chords, continually repeated in positions alternately inverted; consequently, if a long chord be initially divided into any number of such equal portions, its parts will continue to vibrate in the same manner as if they were separate chords; the points of division only remaining always at rest. Such subordinate sounds are called *harmonics:* they are often produced in violins, by lightly touching one of the points of division with the finger, when the bow is applied; and in all such cases it may be shown, by putting small feathers or pieces of paper on the string, that the remaining points of division are also quiescent, while the intervening portions are in motion. This is very well represenied by the following figure.

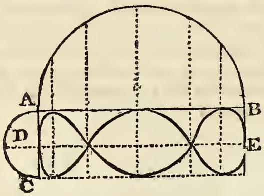


Hence arise the wild and wonderful harmony of the Eolian harp; for though the instrument may have twenty strings, all tuned in unison to one another, yet do we hear not only the natural sound of each string, but its octave, fifth, third, twelfth, fifteenth, &c. A current of air is certainly a delicate fiddlebow, which affords a string an opportunity of dividing itself into a number of imaginary bridges, to which it has a natural tendency. Thus, *a* and *b*, in the following figure,



represent the usual bridges of the string *a*, *c*, *b*, from whence the string has its natural key: the most important imaginary bridge is at *d*, which is in the middle of the string: half the string having but half the *vis inertiæ* of the whole string, will, therefore, vibrate twice as fast as the whole string; every second wave, therefore, coming in contact with the waves of the original string *a b*, gives a pleasing sensation to the ears, and the union is called an octave. Another bridge takes place at *e*; the vibration of *a e* is thrice, while the whole string is twice; hence every third wave of *a e* coincides with every second wave of *a b*, and produces the concord called a fifth. The remaining part of the string *e b*, being half the length of *a e*, is, of course, an octave to *a e*, and a twelfth to the whole string *a b*. The part of the string *c b*, is seven ninths of the whole string, and gives the major third to it, &c. Thus are the leading notes of the octave capable of being performed by one string, or one bell; such is the tendency that motion has to divide itself into proportional parts. The artful performer on the violin avails himself of this tendency, by gently touching the aliquot parts of a string; by which he assists nature in forming the bridges.

It is curious to observe by a microscope, any luminous point on the surface of a vibrating chord; for instance, the reflection of a candle in the coil of a fine wire, wound round it. The velocity of the motion is such, that the path of the luminous point is marked by a line of light, in the same manner as when a burning coal is whirled round; and the figures thus described, are not only different at different parts of the same chord, but they often pass through an amusing variety of forms, during the progress of the vibration; they also vary considerably, according to the mode in which that vibration is excited. The following figure represents a vibration, compounded with another smaller vibration, three times as frequent in a transverse direction, the separate vibrations being such, that the points may be always opposite to a point moving uniformly in a circle. Thus, the vibrations in the lines A B and A C, compose the complicated figure D E.



The following figure exhibits a specimen of the manner in which the vibrations of a string are usually performed, when it is struck with a bow.

OPTICS.

ON VISION.

Having given a comprehensive and popular view of the general theory of Optics, and also explained the construction and use of optical instruments; we shall conclude our observations on this interesting and beautiful branch of Natural Philosophy by making a few general remarks on the sources of light and the nature of vision.

The sources from which light is commonly derived, are either the sun or stars, or such terrestrial bodies as are undergoing those changes which constitute combustion. The process of combustion implies a change in which a considerable emission of light or heat is produced; but it is not capable of a very correct definition: in general it requires an absorption, or at least a transfer of a portion of oxygen; but there appears to be some exceptions to the universality of this distinction; and it has been observed, that both heat and light are often produced where no transfer of oxygen takes place, and sometimes by the effect of a mixture which cannot be called combustion.

Light is also afforded, without any sensible heat, by a number of vegetable and animal substances, which appear to be undergoing a slow decomposition, not wholly unlike combustion. Thus decayed wood, and animal substances slightly salted, often afford spontaneously a faint light, without any elevation of temperature; and it is not improbable that the light of the ignus fatuus may proceed from a vapour of a similar nature.

The effects which are commonly attributed to the motions of the electrical fluid, are often attended by the production of light; and violent and rapid friction frequently seems to be the immediate cause of its appearance. But it is difficult to ascertain whether friction may not be partly concerned in the luminous phenomena attributed to electricity, or electricity in the apparent effects of friction. Light is sometimes produced by friction with a much lower degree of heat than is required for combustion, and even when it is accompanied by combustion, the heat produced by the union of these causes may be very moderate: thus it is usual in some coal mines, to obtain a train of light by the continual collision of flint and steel, effected by the machine called a fire-wheel, in order to avoid setting fire to the inflammable gas emitted by the coal, which would be made to explode if it came near the flame of a candle.

There is a remarkable property, which some substances possess in an eminent degree, and of which few, except metals and water, are entirely destitute. These substances are denominated solar phosphori; besides the light which they reflect and refract, they appear to retain a certain portion, and to emit it again by degrees till it is exhausted, or till its emission is interrupted by cold. The Bolognian phosphorus was one of the first of these substances that attracted notice; it is a sulphate barytes, found in the state of a stone; it is prepared by an exposure to heat, and is afterwards made up into cakes: these, when first placed in a beam of the sun's light, and viewed afterwards in a dark room, have nearly the appearance of a burning coal, or a red hot iron. Burnt oyster-shells and muriate of lime, have also the same property, and some specimens of the diamond possess it in a considerable degree. From the different results of experiments, apparently accurate, made by different persons, there is reason to conclude that some of these phosphori emit only the same kind of light as they have received, while others exhibit the same appearances, to whatever kind of light they may have been exposed. Sometimes it has even been found, that light of a particular colour has been most efficacious in exciting in a diamond the appearance of another kind of light, which it was naturally most disposed to exhibit. The application of heat to solar phosphori, in general expedites the extrication of the light which they have borrowed, and hastens its exhaustion; it also produces in many substances, which are not remarkable for their power of imbibing light, a temporary scintillation, or flashing, at a heat much below ignition. The most remarkable of these are fluor spar in powder, and some other chrystallized substances. It appears that luminous bodies in general emit light equally in every direction, not from each point of any of their surfaces, as some have supposed, but from the whole surface taken together, so that the surface, when viewed obliquely, appears neither more nor less bright than when viewed directly.

The medium of communication, by which we become acquainted with all the objects that we have just been considering, is the eye; an organ that exhibits, to an attentive observer, an arrangement of various substances, so correctly and delicately adapted to the purposes of the sense of vision, that we cannot help admiring, at every step, the wisdom by which each part is adjusted to the rest, and made to conspire in effects so remote from what the mere external appearance promises, that we have only been able to understand, by means of a laborious investigation, the nature and operations of this wonderful structure, while its whole mechanism still remains far beyond all rivalship of human art.

Having already described the various parts of this delicate and curious organ; at page 39, vol. i., it is unnecessary to say any thing here of the eye itself, we shall therefore confine our remarks to the case of objects viewed by that organ.

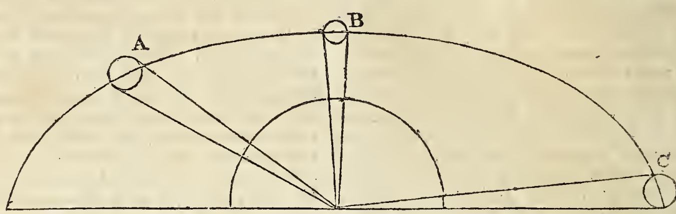
Opticians have often puzzled themselves, without the least necessity, in order to account for our seeing objects in their natural erect position, while the image on the retina is in reality inverted: but surely the situation of a focal point at the upper part of the eye, could be no reason for supposing the object corresponding to it to be actually elevated. We call that the lower end of an object which is next the ground; and the image of a trunk of a tree being in contact with the image of the ground on the retina, we may naturally suppose the trunk itself to be in contact with the actual ground: the image of the branches being more remote from that of the ground, we necessarily infer that the branches are higher and the trunk lower: and it is much simpler that we should compare the image of the floor with the image of our feet, with which it is in contact, than with the actual situation of our forehead, to which the image of the floor on the retina is only accidentally near, and with which indeed it would perhaps be impossible to compare it, as far as we judge by the immediate sensations only.

When the attention is not directed to any particular object of sight, the refractive powers of the eye are adapted to the formation of an image of objects at a certain distance only, which is different in different individuals, and also generally increases with increasing age. Thus, if we open our eyelids suddenly, without particular preparation, we find that distant objects only appear as distinct as we are able to make them; but by an exertion of the will, the eye may be accommodated to the distinct perception of nearer objects, yet not of objects within certain limits. Between the ages of 40 and 50, the refractive powers of the eye usually begin to diminish, but it sometimes happens that where they are already too great, the defect continues unaltered to an advanced age.

We estimate distances much less accurately with one eye than with both, since we are deprived of the assistance usually afforded by the relative situation of the optical axis; thus we seldom succeed at once in attempting to pass a finger or a hooked rod sideways through a ring, with one eye shut. Our idea of distance is also usually regulated by a knowledge of the real magnitude of an object, while we observe its angular magnitude; and on the other hand, a knowledge of the real or imaginary distance of the object often directs our judgment of its actual magnitude. The quantity of light intercepted by the air interposed, and the intensity of the blue tint which it occasions, are also elements of our involuntary calculations: hence, in a mist, the obscurity increases the apparent distance, and consequently the supposed magnitude of an unknown object. We naturally observe, in estimating a distance, the number and extent of the intervening objects; so that a distant church in a woody and hilly country, appears more remote than if it were situated in a plain; and for a similar reason, the apparent distance of an object seen at sea, is smaller than its true distance. The city of London is unquestionably larger than Paris; but the difference appears at first sight much greater than it really is; and the smoke produced by the coal fires of London, is probably the principal cause of the deception.

The sun, moon, and stars, are much less

luminous when they are near the horizon, than when they are more elevated, on account of the greater quantity of their light that is intercepted in its longer passage through the atmosphere: we also observe a much greater variety of nearer objects almost in the same direction; we cannot, therefore, help imagining them to be more distant when they rise or set, than at other times: and since they subtend the same angle, they appear to be actually larger. For similar reasons the apparent figure of the starry heavens, even when free from clouds, is that of a flattened vault, its summit appearing to be much nearer to us than its horizontal parts, and any of the constellations seems to be considerably larger when it is near the horizon, than when in the zenith. This will be understood by a reference to the following figure, where the curve A B C represents the apparent form of the heavens,



therefore when the sun or moon is at A or C, it will appear much larger than at B.

The faculty of judging of the actual distance of objects, is an impediment to the deception, which it is partly the business of a painter to produce. Some of the effects of objects at different distances, may, however, be imitated in painting on a plane surface. Thus, supposing the eye to be accommodated to a given distance, objects at all other distances may be represented with a certain indistinctness of outline, which would accompany the images of the objects themselves on the retina: and this indistinctness is so generally necessary, that its absence has the disagreeable effect called hardness. The apparent magnitude of the subjects of our design, and the relative situations of the intervening objects, may be so imitated by the rules of geometrical perspective, as to agree perfectly with nature; and we may still further improve the representation of distance, by attending to the art of perspective, which consists in a due observation of the loss of sight, and the bluish tinge, occasioned by the interposition of a greater or less depth of air between us, and the different parts of the scenery.

In the panoramas now exhibiting in London, and many other parts of Europe, the effects of natural scenery are very closely imitated; the deception is favoured by the absence of all other visible objects, and by the faintness of the light, which assists in concealing the defects of the representation, and for which the eye is usually prepared, by being long detained in the dark winding passages, which lead to the place of exhibition.

The impressions of light on the retina, appear to be always in a certain degree permanent, and the more so as the light is stronger; but it is uncertain whether the retina possesses this property, merely as a solar phosphorus, or in consequence of its peculiar organization. The duration of the impression is generally from one hundredth of a second, to half a second or more; hence a luminous object revolving in a circle, makes a lucid ring; and a shooting star leaves a train of light behind it, which is not always real. If the object is painfully bright, it generally produces a permanent spot, which continues to pass through various changes of colour for some time, without much regularity, and gradually vanishes: this may, however, be considered as a morbid effect.

When the eye has been fixed on a small object of a bright colour, and is then turned away to a white surface, a faint spot, resembling in form and magnitude the object first viewed, appears on the surface, of a colour opposite to the first; that is, of such a colour as would be produed by withdrawing it from white light; thus, a red object produces a bluish green spot; and a bluish green object a red spot. The reason of this appearance, is probably that the portion of the retina, or of the sensorium, that is affected, has lost a part of its sensibility to the light of that colour with which it has been impressed; and is more strongly affected by the other constituent parts of the white light.

CHEMISTRY.

OF PLATINA.

Dr. Lewis found that gold united with platinum when they were melted together in a strong heat. He employed only crude platina; but Vauquelin, Hatchett, and Klaproth, have since examined the properties of the alloy of pure platinum and gold. To form the alloy, it is necessary to fuse the metals with a strong heat, otherwise the platinum is only dispersed through the gold. When gold is alloyed with this metal, its colour is remarkably injured; the alloy having the appearance of bell metal, or rather of tarnished silver. Dr. Lewis found, that when the platinum amounted only to $\frac{1}{6}$th, the alloy had nothing of the colour of gold; even $\frac{1}{42}$d part of platinum greatly injured the colour of the gold. The alloy formed by Mr. Hatchett of nearly eleven parts of gold to one of platinum, had the colour of tarnished silver. It was very ductile and elastic. From Klaproth we learn, that if the platinum exceed $\frac{1}{17}$th of the gold, the colour of the alloy is much paler than gold; but if it be under $\frac{1}{17}$th, the colour of the gold is not sensibly altered. Neither is there any alteration in the ductility of the gold. Platinum may be alloyed with a considerable proportion of gold, without sensibly altering its colour. Thus an alloy of one part of platinum with four parts of gold can scarcely be distinguished in appearance from pure platinum. The colour of gold does not become predominant till it constitutes eight-ninths of the alloy.

From these facts it follows, that gold cannot be alloyed with $\frac{1}{10}$th of its weight of platinum, without easily detecting the fraud by the debasement of the colour; and Vauquelin has shewn, that when the platinum does not exceed $\frac{1}{10}$th, it may be completely separated from gold by rolling out the alloy into thin plates, and digesting it in nitric acid. The platinum is taken up by the acid, while the gold remains. But if the quantity of platinum exceeds $\frac{1}{30}$th, it cannot be separated completely by that method.

Some trinkets and utensils for the table have already been made of platina; but though they have the advantage of being unalterable and infusible, they have the real defect of not possessing a fine colour, and are at the same time very ponderous. Platina, therefore, can be employed only for small and slender instruments, capable of being exposed to several corrosive matters, and to the air, without being altered by them; but this use is confined within narrow bounds.

By mixing it with copper and arsenic, in various proportions, mirrors for telescopes have been fabricated of it, which will never experience any alteration in their polish, and which unite with a bright and perfectly uniform polish of surface, a complete incapability of being altered by any possible agent.

Platina also promises the greatest and most important advantages in mechanics, and particularly in the delicate art of making time-pieces. The construction of a great number of machines will gain by the acquisition of this metal, which may be substituted in numerous cases for copper, iron, and even silver.

SILVER.

Silver was known to the nations of antiquity. Its discovery is of an earlier date than the most ancient records of mankind; and it soon became, by its scarcity, its beauty, and its useful properties, the object of the researches of a great number of artists and men of science. It is not astonishing that men, who had caused the metallic substances to assume so many different forms, and who so frequently imitated by alloys the whiteness and several of the properties of silver, harboured from a very remote period the idea of creating this precious metal by art. When they compared it with the other white metals, it seemed to them to differ from them only in some qualities, and that it would not be impossible to procure it free from those qualities. Not discouraged by their first unsuccessful attempts, in proportion as this precious metal became amongst mankind the representative of all other objects, of all the productions of industry, and even of those of genius, the alchemists redoubled their efforts; and though their experiments and their laborious researches have not had all the success which they expected from them, they have not been entirely lost. It is from these unfortunate trials, accumulated by the labours of ages, that Chemists have derived the facts which they have employed in its history; and they have had, as it were, nothing more to do than to arrange, in a methodical order, and clearly to describe the phenomena which this metal had presented, in the tortures of every kind to which alchemists have subjected it.

Whilst the alchemists, who called silver *Luna* or *Diana*, qualified it, even by the sign which they consecrated to it, as a kind of semi-gold, which they represented by two semi-circular lines put together in the same direction, with the horns turned to the left; so that nothing more was necessary than to turn back the interior curve, and unite it with the exterior, in order to form the circular figure, or characteristic sign of gold, to which they believed it to be in fact very nearly related, since it was only required to develope one of its parts, in order to cause it to pass into the state of gold, the last stage of metallic perfection. The labours of the alchemists have extended its numerous uses, and have been no less useful to the chemists in constructing the system of their science. The pharmaceutical operations themselves, though they have been much less numerous upon silver than upon many other metals, have served to increase the stock of chemical knowledge concerning this metal; and it is from the whole of these labours that the history of this important metal has gradually been formed.

Silver is of a fine white colour, and of an extremely lively brilliancy. Whether burnished or otherwise, this metal is the most beautiful that is known, at least in the opinion of most men. In general, it pleases more than any other metallic substance. There is no metal that approaches it in lustre; it holds only the fifth rank amongst the metals with respect to density and specific gravity; it follows after platina, gold, tungsten, mercury, and lead. Its specific gravity is 10·474 when melted, and 10·535 when hammered.

With respect to its hardness, it has been placed between iron and gold; this is, however, augmented by the action of the hammer, or by pressure. Its elasticity is pretty considerable; and in this respect it is intermediate between gold and copper. It is one of the most sonorous metals, and when struck, it emits a very acute sound.

The ductility of silver is one of its most marked properties; it follows immediately after gold and platina. It is made into leaves so thin, that they are easily wafted away by the wind, and into wires of extreme tenuity. On this account it is instanced in Natural Philosophy, to prove the divisibility of matter. A grain of silver may be sufficiently extended, and at the same time sufficiently firm, to make an hemispherical vessel to contain an ounce of water, or a wire 400 feet in length. It is upon this amazing malleability that the art of gold and silver-beating is founded. It holds the second rank after gold with respect to tenacity, or resistance against breaking. A wire of this metal, one tenth of an inch in diameter, supports a weight of 270 pounds before it breaks. This wire is considerably lengthened before it breaks. Silver is hardened by all kinds of pressure; but it easily acquires its former ductility again by the action of fire, or by annealing.

Silver is a very good conductor of caloric, and becomes heated very quickly. Its expansion by heat is a little inferior to that of lead and tin, and superior to that of iron. When silver has been expanded by heat, and the fire urged till it is heated to whiteness or incandescence, it softens and runs. Its fusibility has been estimated by Mortimer at 1000 degrees of Fahrenheit. When silver has been fused and suffered to cool slowly, it presents at its surface figures similar to net work and fern-leaves, which announce a very marked crystallizability. On breaking it we find a granulated texture, which possesses the same property. Mongez and Tillet, by suffering a liquid portion to run off from a large mass of fused silver, have obtained it crystallised in quadrangular or octahedral prisms; and it affects the same form in nature, as will be afterwards noticed.

ASTRONOMY.

OF THE STRATUS.

This modification has a mean degree of density.

It is the lowest of clouds, since its inferior surface commonly rests on the earth or water, as represented by the following figure.

Contrary to the last, which may be considered as belonging to the day, this is properly the cloud of night; the time of its first appearance being about sun-set. It comprehends all those creeping mists which in calm evenings ascend in spreading sheets (like an inundation of water) from the bottom of valleys and the surface of lakes, rivers, &c.

Its duration is frequently through the night.

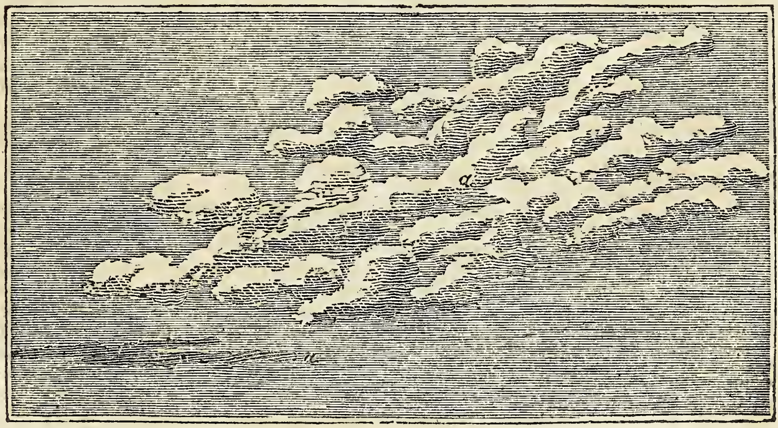
On the return of the sun the level surface of this cloud begins to put on the appearance of cumulus, the whole at the same time separating from the ground. The continuity is next destroyed, and the cloud ascends and evaporates, or passes off with the appearance of the nascent cumulus.

This has been long experienced as a prognostic of fair weather, and indeed there is none more serene than that which is ushered in by it. The relation of the stratus to the state of the atmosphere as indicated by the barometer, &c. appears notwithstanding to have passed hitherto without much attention.

OF THE CIRRO-CUMULUS.

The cirrus having continued for some time increasing or stationary, usually passes either to the cirro-cumulus or the cirro-stratus, at the same time descending to a lower station in the atmosphere.

The cirro-cumulus is formed from a cirrus, or from a number of small separate cirri, by the fibres collapsing as it were, and passing into small roundish masses, in which the texture of the cirrus is no longer discernible, although they still retain somewhat of the same relative arrangement, as exhibited by the following figure.



This change takes place either throughout the whole mass at once, or progressively from one extremity to the other. In either case, the same effect is produced on a number of adjacent cirri at the same time and in the same order. It appears in some instances to be accelerated by the approach of other clouds.

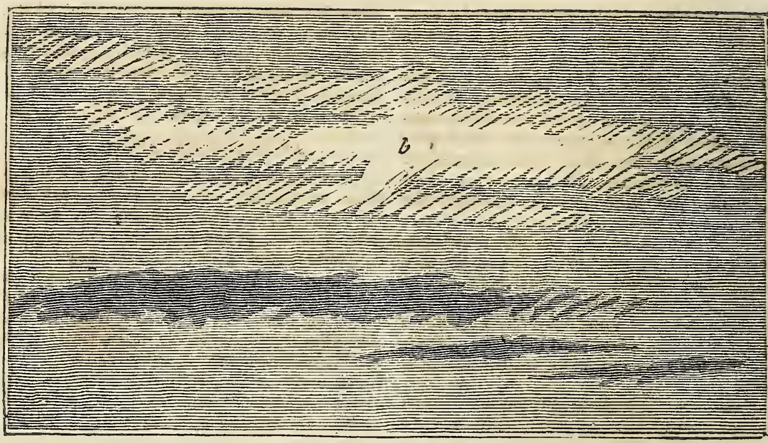
This modification forms a very beautiful sky; sometimes exhibiting numerous distinct beds of these small connected clouds, floating at different altitudes.

The cirro-cumulus is frequent in summer, and is attendant on warm and dry weather. It is also occasionally and more sparingly seen in the intervals of showers, and in winter.

It may either evaporate or pass to the cirrus or cirro-stratus.

OF THE CIRRO-STRATUS.

This cloud appears to result from the subsidence of the fibres of the cirrus to a horizontal position, at the same time that they approach towards each other laterally. The form and relative position, when seen in the distance, frequently give the idea of shoals of fish. Yet in this, as in other instances, the structure must be attended to rather than the form, which varies much, presenting at other times the appearance of parallel bars, interwoven streaks like the grain of polished wood, &c. It is always thickest in the middle, or at one extremity, and extenuated towards the edge, as represented by the following figure.

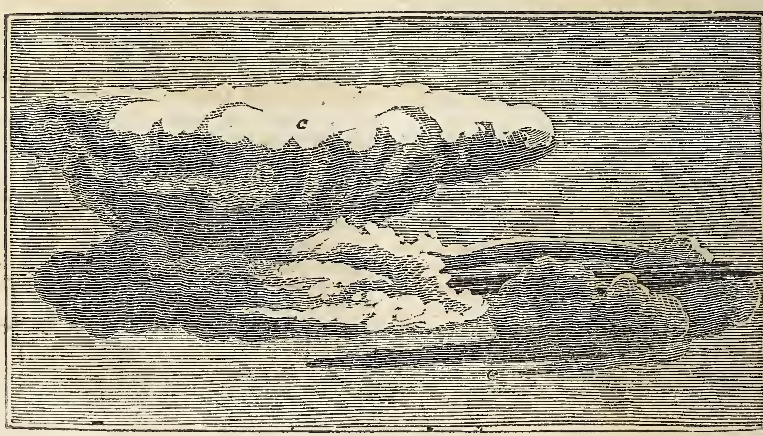


The distinct appearance of a cirrus does not always precede the production of this and the last modification.

The cirro-stratus precedes wind and rain, the near or distant approach of which may sometimes be estimated from its greater or less abundance and permanence. It is almost always to be seen in the intervals of storms. Sometimes this and the cirro-cumulus appear together in the sky, and even alternate with each other in the same cloud, when the different evolutions which ensue are a curious spectacle, and a judgment may be formed of the weather likely to ensue by observing which modification prevails at last. The cirro-stratus is the modification which most frequently and completely exhibits the phenomena of the solar and lunar halo, and (as supposed from a few observations) the parhelion and paraselene also. Hence the reason of the prognostic for foul weather, commonly drawn from the appearance of the halo.

OF THE CUMULO-STRATUS.

The different modifications which have been just treated of, sometimes give place to each other, at other times two or more appear in the same sky; but in this case the clouds in the same modification lie mostly in the same plane of elevation; those which are more elevated appearing through the intervals of the lower, or the latter showing dark against the lighter ones above them. When the cumulus increases rapidly, a cirro-stratus is frequenty seen to form around its summit, reposing thereon as on a mountain, while the former cloud continues discernible in some degree through it. This state continues but a short time. The cirro-stratus speedily becomes denser and spreads, while the superior part of the cumulus extends itself and passes into it, the base continuing as before, and the convex protuberances changing their position, till they present themselves laterally and downward. These are well represented by the following figure.



More rarely the cumulus alone performs this evolution, and its superior part constitutes the incumbent cirro-stratus.

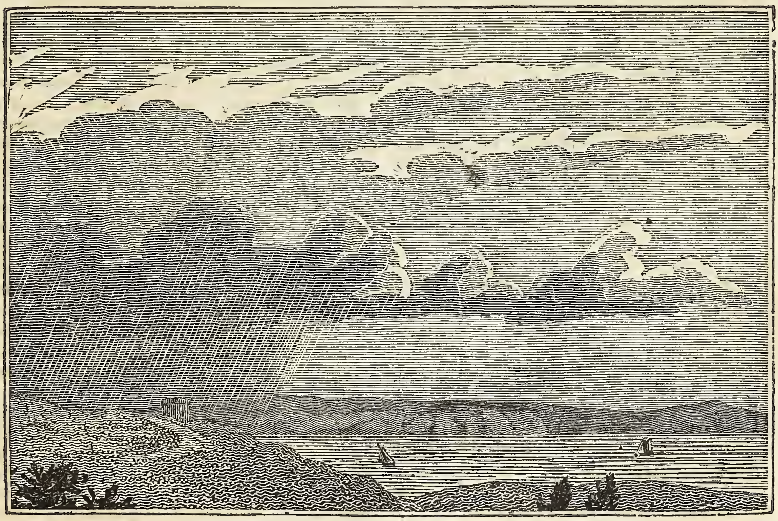
In either case a large lofty dense cloud is formed, which may be compared to a mushroom with a very thick short stem. But when a whole sky is crowded with this modification, the appearances are more indistinct. The cumulus rises through the interstices of the superior clouds, and the whole, seen as it passes off in the distant horizon, presents to the fancy mountains covered with snow, intersected with darker ridges and lakes of water, rocks and towers, &c. The distinct cumulo-stratus is formed in the interval between the first appearance of the fleecy cumulus and the commencement of rain, while the lower atmosphere is yet too dry; also during the approach of thunder storms: the indistinct appearance of it is chiefly in the longer or shorter intervals of showers of rain, snow, or hail.

The cumulo stratus chiefly affects a mean state of the atmosphere as to pressure and temperature; but in this respect, like the other modifications, it affords much room for future observation.

OF THE NIMBUS, OR CUMULO-CIRRO-STRATUS.

Clouds, in any of the preceding modifications, at the same degree of elevation, or in two or more of them, at different elevations, may increase so as completely to obscure the sky, and at times put on an appearance of density, which to the inexperienced observer indicates the speedy commencement of rain. It is nevertheless extremely probable, as well from attentive observation as from a consideration of the several modes of their production, that the clouds, while in any one of these states, do not at any time let fall rain.

Before this effect takes place, they have been uniformly found to undergo a change, attended with appearances sufficiently remarkable to constitute a distinct modification, which is represented by the following figure, called the Nimbus, or Cumulo-cirro-stratus cloud.



In this figure a shower is represented as coming from behind an elevated point of land.

The nimbus, although in itself one of the least beautiful clouds, is yet now and then superbly decorated with its attendant the rainbow; which can only be seen in perfection, when backed by the widely extended uniform gloom of this modification.

The relations of rain, and of periodical showers more especially, with the varying temperature, density, and electricity of the atmosphere, will probably now obtain a fuller investigation, and with a better prospect of success, than heretofore.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF JOHN WALLIS, D. D.

Dr. Wallis was the son of the Rev. John Wallis, M. A. minister of Ashfold, in Kent, and was born in November, 1616: his father dying when he was young, he was indebted for his education to the care and kindness of his mother, who sent him to school, first to Tenterden, in his native county, and afterwards to Felsted, in Essex, where he became pretty well acquainted with the Latin and Greek languages, and also obtained some knowledge of Hebrew. Being at home during the Christmas vacation, he learnt from a younger broher the first rules of common arithmetic, which was his initiation into mathematics, and all the teaching he had; but he afterwards prosecuted it as a pleasing diversion at spare hours, for mathematics was not at that time looked upon as academical learning. In the year 1632, he was sent to the university of Cambridge, and there admitted in Emanuel college, under the tuition of Mr. Anthony Burgess, a pious, learned, and able scholar, a good disputant, an eminent preacher, and afterwards minister of Sutton Colefield, in Warwickshire. Dr. Wallis proceeded Bachelor of Arts in 1637, and Master of Arts in 1640: he entered into orders, and was ordained by Bishop Curle. He was afterwards Fellow of Queen's college, Cambridge, but quitted his fellowship on his marriage in 1644. About this time he was also appointed one of the secretaries to the Assembly of Divines at Westminster; and during his attendance on the assembly, he was a minister in London, first in Fenchurch-street, and afterwards in Ironmonger-lane, where he continued till his removal to Oxford. There the doctor prosecuted his studies; till he at length attained to such proficiency, as to be reputed one of the first mathematicians of the age in which he lived. "He was (says Mr. Scarborough,) one of the greatest masters of geometry that hath appeared in any of these later ages; the honour of our country, and the admiration of others."—Mr. Oughtred says, "he was a person adorned with all ingenious and excellent arts and sciences, pious and industrious, of a deep and diffusive learning, an accurate judgment in all mathematical studies, and happy and successful to admiration in decyphering the most difficult and intricate writings; which was indeed his peculiar honour, and affords the greatest instance ever known of the force and penetration of the human understanding." We shall here give the reader the doctor's own account of the first outset of this business.

"About the beginning of our civil wars, a chaplain of Sir William Waller showed me, as a curiosity, an intercepted letter written in cypher, (and it was indeed the first thing I had ever seen of the kind); and asked me, between jest and earnest, if I could make any thing of it? and was surprised, when I told him, perhaps I might. It was about ten o'clock when we rose from supper; and I withdrew to my chamber to consider of it. By the number of different characters in it, I judged it could be no more than a new alphabet; and before I went to bed I found it out; which was my first attempt upon decyphering: and I was soon pressed to attempt one of a different character, consisting of numerical figures, extending to four or five hundred numbers, with other characters intermixed, which was a letter from Secretary Windebank, (then in France,) to his son in England; and was a cypher hard enough, not unbecoming a secretary of state. And when, upon importuntiy, I had taken a great deal of pains with it without success, I threw it by; but after some time I resumed it again, and had the good hap to master it.

"Being encouraged by this success beyond expectation, I have ventured upon many others and seldom failed of any that I have attempted for many years; though of late the French methods of cyphers are grown so extremely intricate, that I have been obliged to quit many of them, without having patience to go through with them." The following extracts from the copies of his letters are a convincing proof of his labour and success in it; and that he never gave up a cypher while he had the least hope of succeeding. In a letter to the Earl of Nottingham, who was at that time Secretary to William III. dated August 4th, 1689, he says, "From the time your lordship's servant brought me the letter yesterday morning, I spent the whole day upon it, (scarce giving myself time to eat,) and most part of the night; and was at it again early this morning, that I might not make your messenger wait too long." In another: "I wrote to his lordship the next day, on account of the difficulty I at first apprehended, the papers being written in a hard cypher, and in a language of which I am not thorougly master; but sitting close to it in good earnest, I have (notwithstanding that disadvantage) met with better success, and with more speed than I expected. I have therefore returned to his lordship the papers which were sent me, with an intelligible account of what was there in cypher." Being hard pressed by the Earl of Nottingham, he thus writes at the conclusion of one of his letters: "But, my lord, it is hard service, and I am quite weary. If your honour were sensible how much pains and study it cost me, you would pity me; and there is a proverb of not riding a free horse too hard." The doctor, I suppose, thought it was now high time (after he had decyphered so many letters,) that some notice were taken of his services; he therefore begins to give his lordship the hint: he was a little more plain in his next, wherein he says, "However I am neglected, I am not willing to neglect their majesties' services; and have therefore re-assumed the letters which I had laid by, and which I here send decyphered: perhaps it may be thought worth little, after I have bestowed a great deal of pains upon them, and be valued accordingly; but it is not the first time that the like pains have been taken to as little purpose, by, my lord," &c.—In another appears the following postscript, dated August 15, 1691: "But, my lord, I do a little wonder to receive so many fresh letters from your lordship without taking any notice of what I wrote in my last, which I thought would have been too plain to need a decypherer; certainly your other clerks are better paid, or else they would not serve you."

In a letter to a friend, he says: "It is true, I have had all along a great many good words; that he is my humble servant —my faithful servant—my very faithful servant—that he will not fail to acquaint the king with my diligence and success in this difficult work," &c. But he met with a better master in Lord Arlington, for whom he did not do the tenth part of what he had done for the earl. And as the doctor was thus treated by our own ministers, so he was not used much better by those of the elector of Brandenburgh, for whose service he had decyphered some of the French letters, the contents of which were of great consequence; the decyphering of which quite broke the French king's measures in Poland for that time, and caused his ambassadors to be thrust out with disgrace, to their king's great prejudice and disappointment. Take the doctor's own words: "Mr. Smettan, the elector's envoy, entertained me all the while with a great many fine words and great promises, (which, when decyphered, I found to be nulls,) telling me what imporant service it was to his master, and how well accepted, and what presents I was to receive from him; and in particular, that I was to have a rich medal, with an honourable inscription, and a gold chain of great value, which (he said) he expected by the next post: but after all, he left England without making me the least requital for all my pains and trouble, save that once he invited me to dine with him, which cost me more in coach hire thither and back than would have paid for as good a dinner at an ordinary. I believe that the elector does not know how unhandsomely I have been used; and I take it unkind of his envoy to treat me as a child or as a fool, to be wheedled on to hard services with fine words, and yet to think me so weak as to be unable to understand him; when I had decyphered for them between two and three hundred sheets of very difficult and very different cyphers, they might, I think, at least have offered me porter's pay, if not that of a scrivener. I did not contract with them, but did it frankly; for, having a prince to deal with, I was to presume he would deal like himself." Whether it was in consequence of the doctor's letters, or that they were ashamed of their own ingratitude, or from whatever cause it proceeded, the medal so long talked of, and so long expected, was at last sent. However, though they were so unwilling to reward his services, yet they were desirous to prevent his art of decyphering from dying with him, for which purpose he was solicited by Mr. Leibneitz, by order of George I. then elector of Hanover, to instruct a young gentleman whom he would send over; and desired the doctor to make his own terms. But he excused himself by saying, "that he should always be ready to serve his electoral highness, whenever there should be occasion; but, as his art of decyphering was a curiosity that might be of further service to his own country, he could not think of sending it abroad without the consent of his sovereign."

This was a great act of disinterestedness in the doctor, and deserves the highest commendation; because it is certain he might have made a very advantageous bargain for himself, without the least impropriety of conduct, had he not preferred the good of his country to his own private emolument; and it was, no doubt, considered as such by King William, who settled on him a pension of £100 a year, with survivorship to his grandson, whom he had instructed in the art of decyphering at the particular desire of his majesty. We must now look back, and see the other methods in which his useful pen was employed; and we shall find it at no period idle. About the year 1653 he published his "Tractus de Loquela Grammatica-physicus;" wherein he gives a particular account of the physical or mechanical formation of sounds used in speech, or expressed by the letters of several languages. In the year 1692, he published at Oxford three large folios upon mathematics, with this title, "Mathesis Universalis." Part of the third volume of his "Opera Mathematica," is employed in preserving and restoring divers ancient Greek authors, which were in danger of being lost. In the year 1642, he published a book, entitled, "Truth Tried;" in answer to a treatise written by Lord Brook, entitled "The Nature of Truth." In the year 1653 was published, in Latin, his Grammar of the English Tongue, for the use of foreigners; in which he has a curious observation on words beginning with *cr*, as if they took their meaning from the cross. In his "Praxis Grammatica," he gives us the following jeu-d'esprit, which shows him to have been so well acquainted with the English tongue, as to be able to translate extempore, from the French, an example of joining kindred sound (*sensus*) with kindred words. In the above book the doctor says, "A certain learned French gentleman proposed to me the underwritten four chosen French verses, composed on purpose; boasting from it wonderfully of the felicity of his French language, which expressed kindred senses by kindred words; complaining, in the mean while, of our English one, as very often expressing kindred senses by words conjoined by no relation:

Quand un cordier, cordant, veult corder une corde;
Pour sa corde corder, trois cordons il accorde:
Mais, si un des cordons de la corde déscorde,
Le cordon déscordant fait déscorder la corde.

But, that I might show that this felicity of language was not wanting to our own, immediately, without making choice of fresh matter, I translated verbally the same four verses into the English tongue, retaining the same turn of words which he had observed in his, only substituting the word *twist*, purely English, for the exotic word *cord*, which he expected me to use:

When a twister a-twisting, will twist him a twist,
For the twisting his twist, he three tiwines doth entwist;
But if one of the twines of the twist does untwist,
The twine that untwisteth, untwisteth the twist.

And to them these four others:

Untwirling the twine that untwisted between,
He twirls with his twister the two in a twine:
Then, twice having twisted the twines of the twine,
He twisteth the twine he hath twined in twain.

And these:

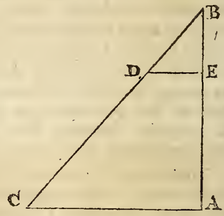
The twain that, in twaining before in the twine,
As twins were entwisted, he now doth untwine;
'Twixt the twain intertwisting a twine more between,
He, twirling his twister, makes a twist of the twine.

(*To be continued.*)

SOLUTIONS OF QUESTIONS.

Quest. 55, *answered by* Mr. J. Holroyd. (*the Proposer.*)

Imagine C A B the right angled triangle; then, (from the latter part of the question) it is plain that the traveller in the road AB will have finished his journey; when the other is $2\frac{1}{2}$ miles distant from the town B,



(as suppose) at the point D; draw the line D E parallel to the given base A C; then the side C A of the triangle C A B, and the side D B of the triangle D E B, being both given, as well as the ratio of C B to A B; it follows (by Euclid v. 13), that C B : A B :: D B : E B $=$ 2, and by Euclid i. 47, D E is found to be $1\frac{1}{2}$ miles; consequently, by similar triangles D E : C A :: E B : A B $= 26\frac{2}{3}$ miles, whence CB is found to be $33\frac{1}{3}$ miles.

We received two other answers to this question; but they were both inaccurate, and much more complex than the above. We cannot, however, allow that this solution is a geometrical one.

Quest. 56, *answered by* Mr. Whitcombe, *Cornhill.*

Let P denote the sum Fig receives from Premium, R $=$ 1·05 the amount of £1, with its interest for 1 year (considering the interest to be 5 per cent.) and let t denote the required number of years Premium ought to live; then per the doctrine of annuities, and per question, we obtain this equation $2P - PR^t = 0$; consequently $2P = PR^t$; therefore $R^t = 2$, and per the nature of logarithms $t \times \log. R = \log. 2$; hence it is manifest, that $t = \frac{\log. 2}{\log. R} =$ 14 years 75 days, the time Premium ought to live, as required.

This question was also correctly answered by the Proposer.

QUESTION FOR SOLUTION.

Quest. 59, *proposed by* J. Anderson, *Brentford.*

A cylindrical vessel, the diameter of which is 60 inches, and the height 48, is to be filled with water, in which there are two holes, one at the bottom, and one in the side close to the bottom. Supposing these to be opened at the same time, it is required to determine in what time the vessel will be exhausted by the power of gravity alone?

DOCTOR FRANKLIN,

London: Published by William Cole, 10, Newgate Street.

JANY 1825.

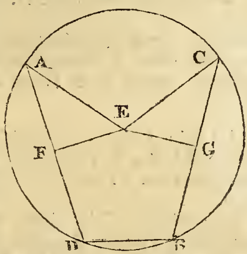
GEOMETRY.

PROPOSITION XIV.

THEOREM.—*Equal straight lines in a circle are equally distant from the centre; and those which are equally distant from the centre, are equal to one another.*

Let the straight lines A B, C D, in the circle A B D C, be equal to one another; they are equally distant from the centre.

Take E the centre of the circle A B D C, and from it draw E F, E G perpendiculars to A B, C D; join A E and E C. Then, because the straight line E F passing through the centre, cuts the straight line



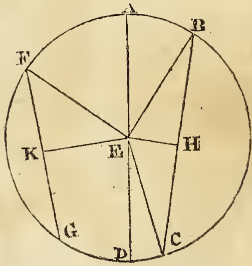
A B, which does not pass through the centre at right angles, it also bisects it: Wherefore A F is equal to F B, and A B double of A F. For the same reason, C D is double of C G: But A B is equal to C D; therefore A F is equal to C G: And because A E is equal to E C, the square of A E is equal to the square of E C: Now the squares of A F, F E are equal to the square of A E, because the angle A F E is a right angle; and, for the like reason, the squares of E G, G C are equal to the square of E C: Therefore the squares of A F, F E are equal to the squares of C G, G E, of which the square of A F is equal to the square of C G, because A F is equal to C G; therefore the remaining square of F E is equal to the remaining square of E G, and the straight line E F is therefore equal to E G: But straight lines in a circle are said to be equally distant from the centre, when the perpendiculars drawn to them from the centre are equal: Therefore A B, C D are equally distant from the centre.

Next, if the straight lines A B, C D be equally distant from the centre; that is, if F E be equal to E G, A B is equal to C D. For, the same construction being made, it may, as before, be demonstrated, that A B is double of A F, and C D double of C G, and that the squares of E F, F A are equal to the squares of E G, G C; of which the square of F E is equal to the square of E G, because F E is equal to E G; therefore the remaining square of A F is equal to the remaining square of C G; and the straight line A F is therefore equal to C G: But A B is double of A F, and C D double of C G; wherefore A B is equal to C D, Therefore equal straight lines, &c. Q. E. D.

PROPOSITION XV.

THEOREM.—*The diameter is the greatest straight line in a circle; and, of all others, that which is nearer to the centre is always greater than one more remote; and the greater is nearer to the centre than the less.*

Let A B C D be a circle, of which the diameter is A D, and the centre E; and let B C be nearer to the centre than F G;



A D is greater than any straight line B C, which is not a diameter, and B C greater than F G.

From the centre draw E H, E K perpendiculars to B C, F G, and join E B, E C, E F; and because A E is equal to E B, and E D to E C: A D is equal to E B, E C: But E B, E C are greater than B C; wherefore, also A D is greater than B C.

And, because B C is nearer to the centre than F G, E H is less than E K: But, as was demonstrated in the preceding, B C is double of B H, and F G double of F K, and the squares of E H, H B are equal to the squares of E K, K F, of which the square of E H is less than the square of E K, because E H is less than E K; therefore the square of B H is greater than the square of F K, and the straight line B H greater than F K: and therefore B C is greater than F G.

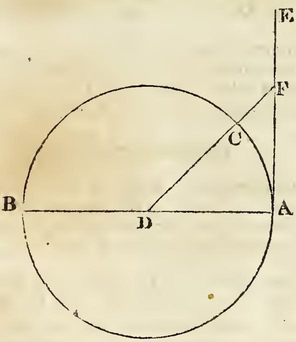
Next, Let B C be greater than F G; B C is nearer to the centre than F G; that is, the same construction being made, E H is less than E K: Because B C is greater than F G, B H likewise is greater than K F: but the squares of B H, H E are equal to the squares of F K, K E, of which the square of B H is greater than the square of F K, because B H is greater than F K; therefore the square of E H is less than the square of E K, and the straight line E H less than E K. Wherefore, the diameter, &c. Q. E. D.

PROPOSITION XVI.

THEOREM.—*The straight line drawn at right angles to the diameter of a circle, from the extremity of it, falls without the circle; and no straight line can be drawn between that straight line and the circumference, from the extremity of the diameter, so as not to cut the circle.*

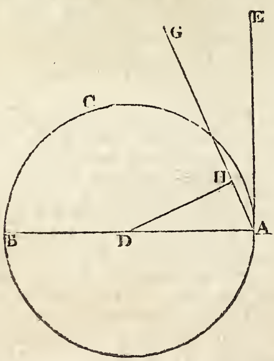
Let A B C be a circle, the centre of which is D, and the diameter A B: and let A E be drawn from A perpendicular to A B, A E shall fall without the circle.

In A E take any point F, join D F, and let D F meet the circle in C. Because



D A F is a right angle, it is greater than the angle A F D; but the greater angle of any triangle is subtended by the greater side, therefore D F is greater than D A; now D A is equal to D C, therefore D F is greater than D C, and the point F is therefore without the circle. And F is any point whatever in the line A E, therefore A E falls without the circle.

Again, between the straight line A E and the circumference, no straight line can be drawn from the point A, which does not cut the circle. Let A G be drawn, in the angle D A E; from D draw D H at



right angles to A G; and because the angle D H A is a right angle, and the angle D A H less than a right angle, the side D H of the triangle D A H is less than the side D A. The point H, therefore, is within the circle, and therefore the straight line A G cuts the circle.

COR. From this it is manifest, that the straight line which is drawn at right angles to the diameter of a circle from the extremity of it, touches the circle; and that it touches it only in one point; because, if it did meet the circle in two, it would fall within it. Also it is evident, that there can be but one straight line which touches the circle in the same point.

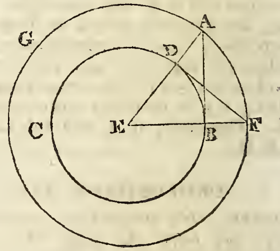
PROPOSITION XVII.

PROBLEM.—*To draw a straight line from a given point, either without or in the circumference, which shall touch a given circle.*

First, let A be a given point without the given circle B C D; it is required to draw a straight line from A, which shall touch the circle.

Find the centre E of the circle, and join AE; and from the centre E, at the distance E A, describe the circle A F G; from the point D draw D F at right angles to E A, and join E B F, and A B. A B touches the circle B C D.

Because E is the centre of the circles B C D, A F G, E A is equal to E F, and E D to E B; therefore the two sides A E,



E B are equal to the two F E, E D, and they contain the angle at E common to the two triangles A E B, F E D; therefore the base D F is equal to the base A B, and the triangle F E D to the triangle A E B, and the other angles to the other angles: Therefore the angle E B A is equal to the angle E D F; but E D F is a right angle, wherefore E B A is a right angle; and E B is drawn from the centre: but a straight line drawn from the extremity of a diameter, at right angles to it, touches the circle: Therefore A B touches the circle; and is drawn from the given point A. Which was to be done.

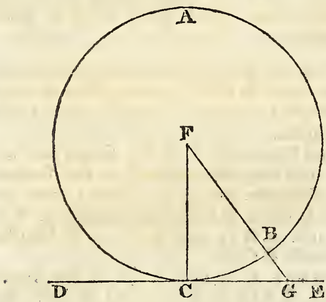
But if the given point be in the circumference of the circle, as the point D, draw D E to the centre E, and D F at right angles to D E; D F touches the circle.

PROPOSITION XVIII.

THEOREM.—*If a straight line touches a circle, the straight line drawn from the centre to the point of contact, is perpendicular to the line touching the circle.*

Let the straight line D E touch the circle A B C in the point C; take the centre F, and draw the straight line F C: F C is perpendicular to D E.

For, if it be not, from the point F draw F B G perpendicular to D E; and because F G C is a right angle, G C F must be an acute angle; and to the greater angle the



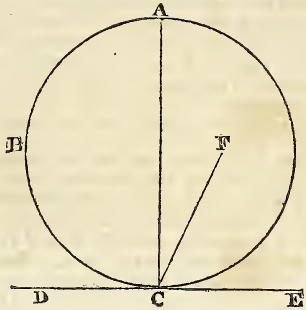
greater side is opposite: Therefore F C is greater than F G; but F C is equal to F B; therefore F B is greater than F G, the less than the greater, which is impossible; wherefore F G is not perpendicular to DE: In the same manner it may bo shown, that no other line but F C can be perpendicular to D E; F C is therefore perpendicular to D E. Therefore, if a straight line, &c. Q. E. D,

PROPOSITION XIX.

THEOREM.—*If a straight line touches a circle, and from the point of contact a straight line be drawn at right angles to the touching line, the centre of the circle is in that line.*

Let the straight line D E touch the circle A B C, in C, and from C let C A be drawn at right angles to D E; the centre of the circle is in C A.

For, if not, let F be the centre, if possible, and join C F: Because D E touches the circle A B C, and F C is drawn from the centre to the point of contact, F C is perpendicular to D E; therefore F C E is a right angle: But A C E is also a right angle; therefore the angle F C E is equal to the angle A C E, the less to the greater, which is impossible: Wherefore F is not the centre of the circle A B C: In the same



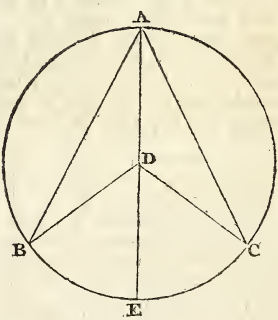
manner it may be shown, that no other point which is not in C A, is the centre; that is, the centre is in C A. Therefore, if a straight line, &c. Q. E. D.

PROPOSITION XX.

THEOREM.—*The angle at the centre of a circle is double of the angle at the circumference, upon the same base; that is, upon the same part of the circumference.*

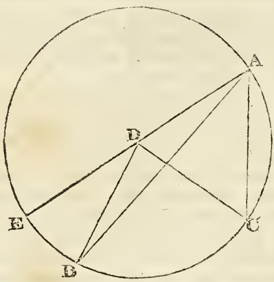
Let A B C be a circle, and B D C an angle at the centre, and B A C an angle at the circumference, which have the same circumference B C for their base; the angle B D C is double of the angle B A C.

First, let D, the centre of the circle, be within the angle B A C, and join A D, and produce it to E: Because D A is equal to D B, the angle D A B is equal to the angle D B A; therefore the angles D A B, D B A



are double of the angle D A B; but the angle B D E is equal to the angles D A B, D B A; therefore also the angle B D E is double of the angle D A B: For the same reason, the angle E D C is double of the angle D A C: Therefore the whole angle B D C is double of the whole angle B A C.

Again, let D, the centre of the circle, be without the angle B A C, and join A D and produce it to E. It may be demonstrated,



as in the first case, that the angle E D C is double of the angle D A C, and that E D B, a part of the first, is double of D A B, a part of the other; therefore the remaining angle B D C is double of the remaining angle B A C. Therefore the angle at the centre, &c. Q. E. D.

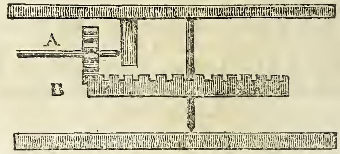
MECHANICS.

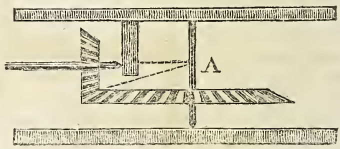
ON THE TEETH OF WHEELS.

If the face of the teeth, where they are in contact, is too much inclined to the radius, their mutual friction is not much affected, but a great pressure on their axis is produced; and this occasions a strain on the machinery, as well as an increase of friction on the axis.

If it be desired to produce a great angular velocity, with the smallest possible quantity of wheel-work, the diameter of each wheel must be between three and four times as great as that of the pinion on which it acts, where the pinion impels the wheel; it is sometimes made with three or four teeth only: but it is much better in general to have at least six or eight; and considering the additional labour of increasing the number of wheels, it may be advisable to allot more teeth to each of them, than the number resulting from the calculation; therefore we may allow 30 or 40 teeth to a wheel, acting on a pinion of 6 or 8. In works which do not require a great degree of strength, the wheels have sometimes a much greater number of teeth than this; and on the other hand, an endless screw or a spiral acts as a pinion of one tooth, since it propels the wheel through the breadth of one tooth only by each revolution. For a pinion of six teeth, it would be better to have a wheel of 35 or 37 than 36; for each tooth of the wheel would thus act in turn upon each tooth of the pinion, and the work would be more equally worn, than if the same teeth continued to meet in each revolution. The teeth of the pinion should also be somewhat stronger than those of the wheel, in order to support the more frequent recurrence of friction. It has been proposed, for the coarser kinds of wheel-works, to divide the distance between the middle points of two adjoining teeth into 30 parts, and to allot 16 to the tooth of the pinion, and 13 to that of the wheel, allowing one for freedom of motion.

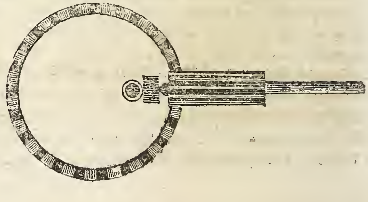
The wheel and pinion may either be situated in the same plane, both being commonly of the kind denominated *spur-wheels*, or their planes may form an angle: in this case one of them may be a *crown* or *contrate* wheel, as represented by the first of the following figures,





where A is a spur and B a crown-wheel, or both of them may be bevilled, the teeth being cut obliquely, as in the second figure, where the wheel and pinion are both bevilled, the faces of the teeth being directed to the point A. According to the relative magnitude of the wheels, the angle of the bevil must be different, so that the velocities of the wheels may be in the same proportion at both ends of their oblique faces; for this purpose, the faces of all the teeth must be directed to the point where the axis would meet.

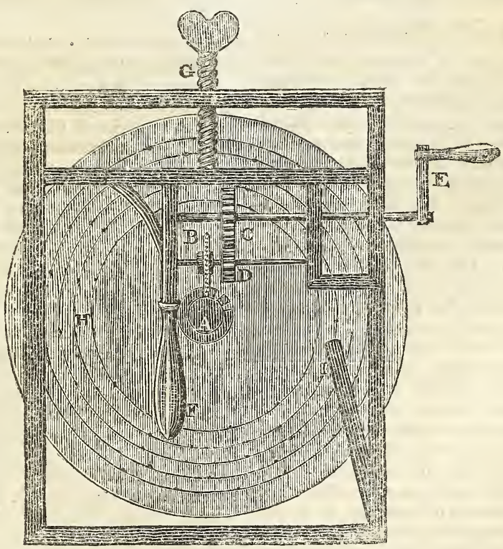
In cases where a motion not quite equable is required, as it sometimes happens in the construction of clocks, but more frequently in orreries, the wheels may either be divided a little unequally, or the axis may be placed a little out of the centre; and these eccentric wheels may either act on other eccentric wheels, or, if they are made as contrate wheels, upon a lengthened pinion, as represented by the annexed figure.



An arrangement is sometimes made for separating wheels, which are intended to turn each other, and for replacing them at pleasure; the wheels are said to be thrown by these operations out of gear, and into gear again.

When a wheel revolves round another, and is so fixed as to remain nearly in a parallel direction, and to cause the central wheel to turn round its axis—the apparatus is called a *sun*-and-*planet wheel*, (see page 227, vol. i.) In this case, the circumference of the central wheel moves as fast as that of the revolving wheel, each point of which describes a circle, equal in diameter to the distance of the centres of the two wheels: consequently, when the wheels are equal, the central wheel makes two revolutions, every time that the exterior wheel travels round it. If the central wheel be fixed, and the exterior wheel be caused to turn on its own centre during its revolution, by the effect of the contact of the teeth, it will make in every revolution one turn more with respect to the surrounding objects, than it would make, if its centre were at rest, during one turn of the wheel which is fixed: and this circumstance must be recollected when such wheels are employed in the construction of *planetariums*.

Wheels are usually made of wood, of iron, either cast or wrought, of steel, or of brass. The teeth of metal wheels are generally cut by means of a machine; the wheel is fixed on an axis, which also carries a plate furnished with a variety of circles, divided into different numbers of equal parts, marked by small excavations; these are brought in succession under the point of a spring, which holds the axis firm, while the intervals between the teeth are expeditiously cut out by a revolving saw of steel. The teeth are afterwards finished by a file; and a machine has also been invented for holding and working the file. This machine is represented by the following figure:



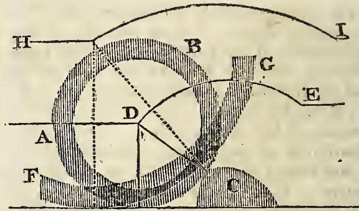
A is the wheel, of which the teeth is formed by the revolving saw B, turned by the wheel and pinion C D, by means of the handle E, while the frame, which holds the saw, moving on hinges, and resting on a spring, is depressed by the handle F, its place having been previously adjusted by the screw G. The large plate H I contains a number of concentric circles, variously divided by points, into which the end of the spring I sinks at each step, so as to fix the apparatus in the required position.

Toothed wheels are employed in mechanics, not only for increasing or diminishing velocity, so as to adapt a given power to the purpose of producing a certain effect, as in a common mill, where the slow motion of the water-wheel is made to produce the rapid motion of the mill-stone; but they are also employed for the purpose of producing angular motions, that shall obtain, with great precision, given ratios to one another. This happens in clock work, and it is there of importance to determine, with accuracy, the number of wheels and the number of teeth in each; but this is a branch of mechanics, which we considered too abstruse to be introduced in a work like the present. We may, however, remark, that the number of teeth in a wheel, and in a pinion which work together, should be prime to one another, that their coincidences may not recur in the same order after every revolution.

The numbers expressing the ratio of the angular velocity of the wheel to that of the pinion, may sometimes be fractional, and may consist of so many places, when the fractions are taken away, that, to make the motions exactly in their ratio, would require more wheels, and a greater number of teeth, than can conveniently be allowed. It is then of consequence to find two numbers that will express the ratio, not exactly, but more nearly, than can be done by smaller numbers, The method of finding such numbers is, however, too intricate to be given here.

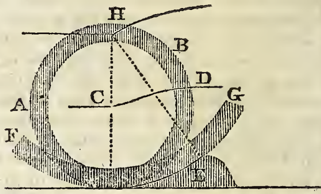
ON WHEEL CARRIAGES.

Though we have already treated pretty fully of the friction of axles at page 215, vol. i. yet the subject of wheel carriages forms so important a part of mechanics, that we shall devote a few pages to its consideration. The wheels of carriages owe a great part of their utility to the diminution of friction, which is as much less in a carriage than a dray, as the diameter of the axle is less than that of the wheel, even supposing the dray to slide on a greased surface of iron. The wheels also assist us in drawing the carriage over an obstacle, for the path which the axis of the wheel describes, is always smoother and less abrupt than the surface of a rough road on which the wheel rolls. It is obvious, that both these advantages are more completely attained by large wheels than by smaller ones: the dimensions of the axis not being increased in the same proportion with those of the wheel, and the path of the axis to which that of the centre of gravity is similar, consisting of portions of larger circles, and consequently being less curved; and if the wheels are elastic, and rebound from an obstacle, the difference is still increased. It is, however, barely possible, that the curvature of the obstacles to be overcome, may be intermediate between those of a larger and of a smaller wheel; and in this case the higher wheel will touch a remoter part of the obstacle, so that the path of the axis will form an abrupt angle, while the smaller wheel follows the curve, and produces a more equable motion. For example, the centre of the wheel A B, passing over the obstacle C, describes the path D E;



and that of the larger wheel F G, the path H I, which is less steep.

Again, the centre of the wheel A B describes the curved path C D,



in passing over the obstacle E, while that of the larger wheel F G, has an angle at H.

The greater part of the resistance to the motion of a carriage very frequently varies, from the continual displacement of a portion of the materials of the road, which do not re-act on wheels with perfect elasticity, but undergo a permanent change of form, proportional to the loss of force. Hence, in a soft sand, although the axles of the wheels may move in a direction perfectly horizontal, the draught becomes extremely heavy. The more the wheel sinks, the greater is the resistance; and if we suppose the degree of elasticity of the materials, and their immediate resistance at different depths to be known, we may calculate the effect of their re-action in retarding the motion of the carriage. Thus, if the materials were perfectly inelastic, acting only on the preceding half of the immersed portion of the wheel, and their immediate pressure or resistance were simply proportional to the depth, like that of fluids or of other elastic substances, the horizontal resistance would be to the weight, nearly as the depth of the part immersed to two thirds of its length; but if the pressure increased as the square of the depth, which is a more probable supposition, the resistance would be to the weight as the depth to about four-fifths of the length; the pressure may even vary still more rapidly, and we may consider the proportion of the resistance to the weight, as no greater than that of the depth of the part immersed to its length, or of half this length to the diameter of the wheel; and if the materials are in any degree elastic, the resistance will be lessened accordingly. But on any of these suppositions, it may be shown that the resistance may be reduced to one half, either by making a wheel a little less than three times as high, or about eight times as broad as the given wheel. This consideration is of particular consequence in soft and boggy soils, as well as in sandy countries; thus, in moving timber in a moist situation, it becomes extremely advantageous to employ very high wheels, and they have the additional convenience, that the timber may be suspended from the axles by chains, without the labour of raising it so high, as would be necessary for placing it on a carriage of any kind.

But the magnitude of wheels is practically limited, by the strength or weight of the materials of which they are made, by the danger of overturning when the centre is raised too high, and in case of the first pair of wheels of a four wheel carriage, by the inconvenience that would arise in turning a corner, with a wheel which might interfere with the body of the carriage. It is also of advantage, that the draught of a horse should be in a direction somewhat ascending, partly on account of the shape of the horse's shoulder, and partly because the principal force that he exerts, is in the direction of a line passing through the point of contact of his hind feet with the ground. But a reason equally strong, for having the draught in this direction is, that a part of the force may always be advantageously employed in lessening the pressure on the ground: and to answer this purpose the most effectually, the inclination of the traces or shafts, ought to be the same with that of a road on which the carriage would begin or continue to descend by its own weight only.

In order to apply the force in this manner to both pairs of wheels where there are four, the line of draught ought to be directed to a point half way between them, or rather to a point immediately under the centre of gravity of the carriage; and such a line would always pass above the axis of the fore wheels. If the line of draught pass immediately through this axis, the pressure on the hind wheels will remain unaltered; and if the traces or shafts be fixed still lower, the pressure on the hind wheels will even be somewhat increased by the draught. It is evident, therefore, that this advantage cannot be obtained if the fore wheels are very high; we may also understand, that in some cases the common opinion of the elegibility of placing a load over the fore wheels, rather than the hind wheels, may have some foundation in truth. When several horses are employed, the draught of all but the last must be nearly horizontal; in this case the flexure of the chain brings it into a position somewhat more favourable for the action of the horses; but the same cause makes the direction of its attachment to the waggon unfavourable; further than this, there is no absolute loss of force, but it appears to be advisable to cause the shaft horse to draw in a direction as much elevated as possible; and on the whole it is probable that horses drawing singly have a material advantage, when they do not require additional attendance from the drivers.

The practice of making broad wheels conical, has obviously the disadvantageous effect of producing a friction at each edge of the wheel, when the carriage is moving in a straight line; for such a wheel, if it moved alone, would always describe a circle round the vertex of the cone to which it belongs. When the wheels are narrow, a slight inclination of the spokes appears to be of use in keeping them more steady on the axles than if they were exactly vertical; and when, by an inclination of the body of the carriage, a greater proportion of the load is thrown on the lower wheel, its spokes, being then in a vertical position, are able to exert all their strength with advantage. The axles being a little conical, in order that they may not become loose, or may easily be tightened as they wear, it is necessary that they should be bent down, so that their lower surfaces may be horizontal, otherwise the wheels would press too much on the linch pin. For this reason, the distance between the wheels should be a little greater above than below, and their surfaces of course slightly conical.

ELECTRICITY.

Having stated the fundamental properties of the electric fluid, and of the different kinds of matter as connected with that fluid, we shall now examine its distribution, and the attractive and repulsive effects exhibited by it under different forms and circumstances. The general effect of electrified bodies on each other, if their bulk is small in comparison with their distance is, that they are mutually repelled when in similar states of electricity, and attracted when in dissimilar states. This is a consequence immediately deducible, from the mutual attraction of redundant matter and redundant fluid, and from the repulsion supposed to exist between any two portions, either of matter or of fluid; and it may also be easily confirmed by experimental proof. A neutral body, if it were a perfect non-conductor, would not be affected either way by the neighbourhood of an electrified body: for while the whole matter contained in it remains barely saturated with the electric fluid, the attractions and repulsions balance each other. But in general, a neutral body appears to be attracted by an electrified body, on account of a change of the disposition of the fluid which it contains, upon the approach of a body either positively or negatively electrified. The electrical affection produced in this manner, without any actual transfer of the fluid, is called *induced* electricity.

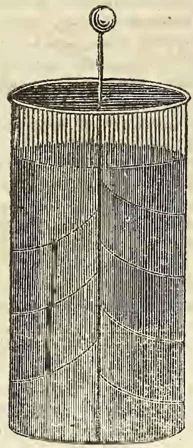
The state of induced electricity may be illustrated, by placing a long conductor at a little distance from an electrified substance, and directed towards it: and by suspending pith balls or other light bodies from it, in pairs, at different parts of its length: these will repel each other, from being similarly electrified, at two ends, which are in contrary states of electricity, while at a certain point towards the middle they will remain at rest, the conductor being here perfectly neutral. It was from the situation of this point, that Lord Stanhope first inferred the true law of the electric attractions and repulsions, although Mr. Cavendish had before suggested the same law as the most probable supposition.

The attraction thus exerted by an electrified body upon neutral substances, is strong enough, if they are sufficiently light, to overcome their gravitation, and to draw them up from a table at some little distance: upon touching the electrified body, if it is a conductor, they receive a quantity of electricity from it, and are again repelled, until they are deprived of their electricity by contact with other substances, which, if sufficiently near to the first, is usually in a contrary state, and therefore renders them still more capable of returning, when they have touched it, to the first substance, in consequence of an increased attraction, assisted also by a new repulsion. This alternation has been applied to the construction of several electrical toys; a little hammer, for example, has been made to play between two bells; and this instrument has been employed for giving notice of any change of the electrical state of the atmosphere. The repulsion which takes place between two bodies, in a similar state of electricity, is the cause of the currents of air which always accompany the discharge of electricity, whether negative or positive, from pointed substances.

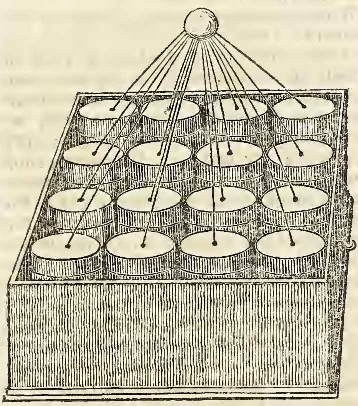
If two bodies approach each other, electrified either positively or negatively in different degrees, they will either repel or attract each other, according to their distance: when they are very remote, they exhibit a repulsive force, but when they are within a certain distance, the effects of induced electricity overcome the repulsion, which would necessarily take place, if the distribution of the fluid remained unaltered by their mutual influence.

When a quantity of electric fluid is accumulated on one side of a non-conducting substance, it tends to drive off the fluid from the other side; and if this fluid is suffered to escape, the remaining matter exerts its attraction on the fluid, which has been imparted to the first side, and allows it to be accumulated in a much greater quantity than could have existed in an equal surface of a conducting substance. In this state, the body is said to be charged; and for producing it the more readily, each surface is usually coated with a conducting substance, which serves to convey the fluid to and from its different parts with convenience. The thinner any substance is, the greater quantity of the fluid is required for charging it in this manner, so as to produce a given tension, or tendency to escape: but if it be made too thin, it will be liable to break the attractive force of the fluid, for the matter on the opposite side overcoming the cohesion of the substance, and perhaps forcing its way through the temporary vacuum which is formed.

When a communication is made in any manner by a conducting substance between the two coatings of a charged plate or vessel, the equilibrium is restored, and the effect is called a shock. If the coatings be removed, the plate will still remain charged, and it may be gradually discharged, by making a communication between its several parts in succession, but it cannot be discharged at once, for want of a common connection; so that the presence of the coating is not absolutely essential to the charge and discharge of the opposite surfaces. Such a coated substance is most usually employed in the form of a jar. Jars were formerly filled with water, or with iron filings; the instrument having been principally made known from the experiments of Musschenbroek and others at Leyden, it was called the Leyden jar or phial; but at present a coating of tin foil is commonly applied on both sides of the jar, leaving a sufficient space at its upper part, to avoid the spontaneous discharge, which would often take place between the coatings, if they approached too near to each other; and a ball is fixed to the cover, which has a communication with the internal coating, and by means of which the jar is charged, while the external coating is allowed to communicate with the ground. This jar is represented by the following figure:



A collection of such jars is called a battery, and an apparatus of this kind may be made so powerful, by increasing the number of jars, as to exhibit many striking effects by the motion of the electric fluid, in its passage from one to the other of the surfaces. The following figure represents a battery, containing 16 jars.



The conducting powers of different substances are concerned, not only in the facility with which the motions of the electric fluid are directed into a particular channel, but also in many cases of its equilibrium, and particularly in the properties of charged substances, which depend on the resistance opposed by nonconductors, to the ready transmission of the fluid. These powers may be compared, by ascertaining the greatest length of each of the substances to be examined, through which a spark or a shock will take its course, in preference to a given length of air, or of any other standard of comparison.

The progressive motion of the electric fluid through conducting substances is so rapid, as to be performed in all cases without a sensible interval of time. It has indeed been said, that when very weakly excited, and obliged to pass to a very great distance, a perceptible portion of time is actually occupied in its passage; but this fact is somewhat doubtful, and attempts have been made in vain, to estimate the interval, employed in the transmission of a shock through several miles of wire. We are not to imagine that the same particles of the fluid which enter at one part, pass through the whole conducting substance, any more than that the same portion of blood, which is thrown out of the heart, in each pulsation, arrives at the wrist, at the instant that the pulse is felt there. The velocity of the transmission of a spark or shock far exceds the actual velocity of each particle, in the same manner as the velocity of a wave exceeds that of the particles of water concerned in its propagation; and this velocity must depend both on the elasticity of the electric fluid, and on the force with which it is confined to the conducting substance. If this force were merely derived from the pressure of the atmosphere, we might infer the density of the fluid from the velocity of a spark or shock, compared with that of sound; or we might deduce its velocity from a determination of its density. It has been supposed, although perhaps somewhat hastily, that the actual velocity is nearly equal to that of light.

The manner in which the electric fluid makes its way, through a more or less perfect nonconductor, is not completely understood: it is doubtful whether the substance is forced away on each side, so as to leave a vacuum for the passage of the fluid, or whether the newly formed surface helps to guide it in its way; and in some cases it has been supposed that the gradual communication of electricity has rendered the substance more capable of conducting it, either immediately, or, in the case of the air, by first rarefying it. However this may be, the perforation of a jar of glass by an overcharge, and that of a plate of air by a spark, appear to be effects of the same kind, although the charge of the jar is principally contained in the glass, while the plate of air is perhaps little concerned in the distribution of the electricity.

The actual direction of the electric current has not in any instance been fully ascertained, although there are some appearances which seem to justify the common denominations of positive and negative. Thus, the fracture of a charged jar of glass, by spontaneous explosion, is well defined on the positive, and splintered on the negative side, as might be expected from the passage of a foreign substance from the former side to the latter; and a candle, held between a positive and a negative ball, although it apparently vibrates between them, is found to heat the negative ball much more than the positive. We cannot, however, place much dependence on any circumstance of this kind, for it is doubtful whether any current of the fluid, which we can produce, possesses sufficient momentum to carry with it a body of sensible magnitude. It is in fact of little consequence to the theory, whether the terms positive and negative be correctly applied, provided that their sense remain determined; and that, like positive and negative quantities in mathematics, they be always understood of states which neutralise each other. The original opinion of Dufay, of the existence of two distinct fluids, a vitreous and a resinous electricity, has at present few advocates, although some have thought such a supposition favoured by the phenomena of the galvanic decomposition of water.

When electricity is simply accumulated without motion, it does not appear to have any effect, either mechanical, chemical, or physiological, by which its presence can be discovered; the acceleration of the pulse, and the advancement of the growth of plants, which have been sometimes attributed to it, have not been confirmed by the most accurate experiments. An uninterrupted current of electricity, through a perfect conductor, would perhaps be also in every respect imperceptible, since the best conductors appear to be the least affected by it. Thus, if we place our hand on the conductor of an electrical machine, the electricity will pass off continually through the body, without exciting any sensation.

The most common effect of the motion of the electric fluid is the production of light. Light is probably never occasioned by the passage of the fluid through a perfect conductor; for when the discharge of a large battery renders a small wire luminous, the fluid is not wholly confined to the wire, but overflows a little into the neighbouring space. There is always an appearance of light whenever the path of the fluid is interrupted by an imperfect conductor; nor is the apparent contact of conducting substances sufficient to prevent it, unless they are held together by a considerable force; thus, a chain, conveying a spark or shock, appears luminous at each link, and the rapidity of the motion is so great, that we can never observe any difference in the times of the appearance of the light in its different parts; so that a series of luminous points, formed by the passage of the electric fluid, between a string of conducting bodies, represents at once a brilliant delineation of the whole figure in which they are arranged. A lump of sugar, a piece of wood, or an egg, may easily be made luminous in this manner; and many substances, by means of their properties as solar phosphori, retain for some seconds the luminous appearance thus acquired. Even water is so imperfect a conductor, that a strong shock may be seen in its passage through it; and when the air is sufficiently moistened or rarefied to become a conductor, the track of the fluid through it is indicated by streams of light, which are perhaps derived from a series of minute sparks passing between the particles of water or of rarefied air. When the air is extremely rare, the light is greenish; as it becomes more dense, the light becomes blue, and then violet, until it no longer conducts.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF JOHN WALLIS, D. D.

(*Continued from page* 32.)

In the year 1653, came out his, "Commercium Epistolicum," being an epistolary correspondence between Lord Brouncker and Dr. Wallis, on one part, and Messrs. Fermate and Frenicle, (two French gentlemen,) on the other; occasioned by a challenge given by Mr. Fermate, to the English, Dutch, and French mathematicians, to answer a numerical question; but this sort of questions were not such as the Doctor was fond of; therefore, at first, he did not pay that attention to it which it seemed to require; but how he succeeded afterwards may be learnt from the following extracts. Sir Kenelm Digby thus writes to the Doctor from Paris: "I beseech you to accept of the profession I here make you, with all truth and sincerity; which is, that I honour most highly your great parts and worth, and the noble productions of your large and knowing mind, which maketh you the honour of our nation, and envy of all others; certainly you have had the satisfaction to have had the two greatest men in France, (Messrs. Fermate and Frenicle) to cope with; and I doubt not but your letter will make them, and all the world, give as large and as full a deference to you. This excellent production of your single brain hath convinced our mathematicians here, that, like Samson, you can easily break and snap asunder all the Philistines' cords and snares, when the assault cometh warmly upon you." Mr. Frenicle writes thus to Sir Kenelm Digby: "I have read over the last letter of the great Dr. Wallis, from which it appears plain to me, how much he excels in mathematical knowledge. I had given my opinion of him dreaming, but now I willingly give my judgment of him waking. Before, I saw Hercules, but it was playing with children; now I behold him destroying monsters at last, going forth in gigantic strength. Now must Holland yield to England, and Paris to Oxford." Thus ended this learned dispute; during which many other ingenious problems were started, and solved, equally to the honour of the doctor.

In 1655, Mr. Thomas Hobbes published "Six Lessons to the Professors of Mathematics in Oxford." Upon this the Doctor wrote an answer, entitled, "Due Correction for Mr. Hobbes, or School Discipline for not saying his Lesson right." About the year 1655 he published his Arithmetic of Infinites, which was evidently the ground work of Sir Isaac Newton's method of Fluxions.

In 1661, he wrote and published sundry tracts, and a great variety of letters, on philosophical, mathematical, and mechanical, subjects. Upon the Restoration he met with great respect; and was not only admitted one of the king's chaplains in ordinary, but likewise confirmed in his two places of Savillian Professor, and keeper of the archives, at Oxford. It does not appear that Dr. Wallis had any considerable church-preferment, nor that he was desirous of it; for, writing to a friend upon that subject, he says, "I have not been fond of being a great man; studying more to be serviceable, than to be great; and therefore have not sought after it." However, in the year 1692, the queen made him the proffer of the deanery of Hereford, which, being not quite agreeable to his mind, he declined; probably not thinking it worth his accepting: for, he observes to a friend upon this occasion, that "It was a proverb, when I was a boy, 'Better sit still than rise to fall.' If I have deserved no better, I shall doubt whether I have deserved this; it being but equivalent to what I have, and with which I am contented: I am an old man, and am not like to enjoy any place long." Thus did that great and good man give his labours to his country, without seeking those emoluments and rewards which others, without the least degree of merit, pursue with the greatest eagerness, and think themselves injured if they do not attain them.

The Doctor lived to a good old age, being upwards of eighty-seven when he died. (October 28, 1703.) He was interred in the choir of St. Mary's church, in Oxford, where a handsome monument is erected to his memory, with a Latin inscription.

ON THE TEMPERING OF STEEL.

The processes invented for the tempering of steel have been so various and so inefficient, that it is of importance to select such as appear to have been attended with success. Among those which have enabled us to give to this operation a degree of certainty previously unknown, may be mentioned the baths of oil, or of a fusible metallic alloy.

Chemists in this country have made repeated experiments for the purpose of determining the degrees of temperature of all the common oils in a state of ebullition, as well as those of the fusion of many metallic alloys composed of bismuth, lead, and tin.

Those who adopt the use of metallic baths for tempering cutting instruments, ought to have them heated in vessels of cast iron, of different sizes and forms, according to the nature of the instruments to be tempered. It would be well to have two of them placed one against the other in the body of a register stove, to intercept at pleasure the communication of the fire, in order to be able to heat the one while the other is tempered. This method presents many advantages.

1. There is, by this means, no uncertainty as to the degree of temperature which ought to be given; for when once the operator has ascertained which of the metallic baths is adapted for the description of instruments that he wishes to temper, he has only to arrange them in a row upon the surface of the solid metal, and kindle a fire to make it melt; but great attention must be paid to remove all the instruments quickly, and to plunge them in cold water the moment the surface of the metal begins to liquefy, because they will then have all equally acquired the same temperature.

2. It is very difficult, not to say impossible, by the ancient method, to give the instruments an equal temperature throughout, when they happen to have thick backs; for frequently the blade is too hot, and even experiences alterations, before the other parts are sufficiently and regularly heated. The new process of metallic baths is of incalculable advantage for tempering large files and rasps, which must be left a very long time in the fire before they become equally heated in all their parts. We are justified in saying that

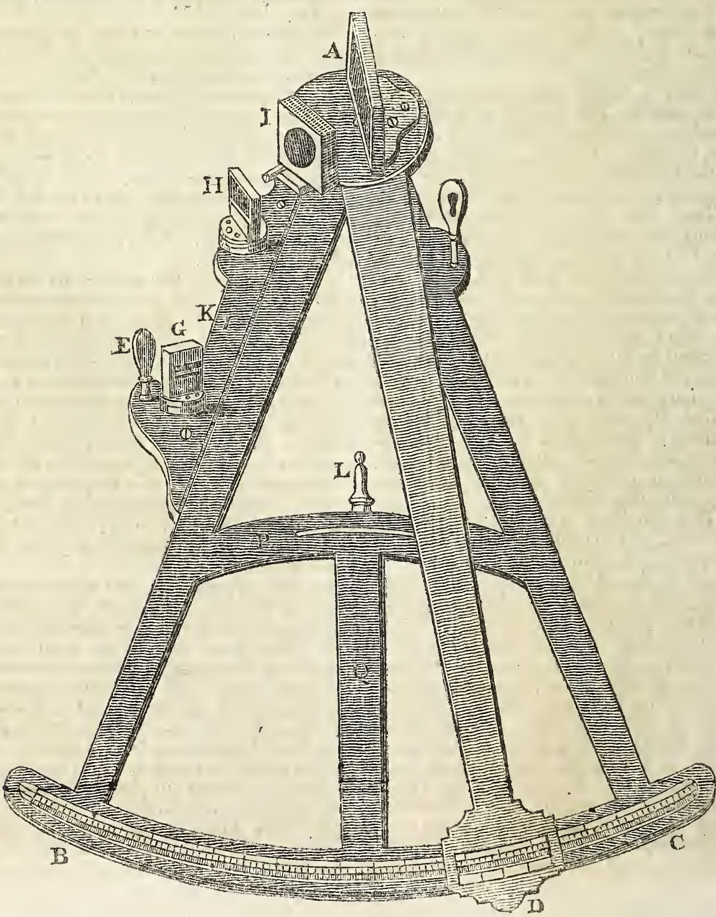
there are no instruments except the largest, such as plough-shares, planes, &c. that cannot be tempered with much more certainty by means of metallic baths, than by the methods formerly in use.

An opinion is pretty generally entertained, that, in the process of tempering, if the steel has been too much heated before immersion, it is necessary to give it a second time an excess of temperature, to bring it back to its proper degree of hardness, and that, unless this be done, a good cutting instrument cannot be made. This is, however, a very injudicious attempt to rectify one inconvenience by another; and a very little reflection will convince a thinking person that the method is altogether vicious, and has produced a great quantity of bad cutlery. It may be safely affirmed, *that the lowest possible temperature at which steel can be tempered, is indisputably the best;* and that to repeat the operation in any manner, must essentially affect its principal properties.

In fact, steel which has undergone too strong a temperature, rarefies, and has neither a fine nor a compact grain. It is so susceptible of alteration at the least degree of heat, that, if ever so slightly exposed to it, its cutting qualities are injured. It will be evident from these observations, that no degree of temperature can restore to steel which has once been over-heated, the properties it has lost. Notwithstanding this, many workmen perform this very delicate operation without any attention, with the idea that they can always repair their negligence by the improper method we have already mentioned.—*(Ann. de la Soc. d'Agr.)*

DESCRIPTION AND USE OF HADLEY'S QUADRANT.

One of the most useful and convenient instruments for measuring the altitude of a celestial object, is Hadley's Quadrant, which is represented by the following figure:



The form of the instrument is an octagonal sector of a circle, and contains 45°; but, because of the double reflexion, the limb is divided into 90°.

A B, and A C, are the two radii, and B C the circle or limb, which, together with the braces, P Q, form the octant, or frame of the quadrant; A is the index glass, H the fore horizon glass, and G the back horizon glass, and E F the corresponding sight vanes; I the coloured glass, the stem of which is put into the hole K, when the back observation is used; and L is a pencil for writing down the observation.

The altitude of any object is determined by the position of the index on the limb, when, by reflection, that object appears in contact with the horizon.

If the object whose altitude is to be observed be the sun, and if so bright that its image may be seen in the transparent part of the fore horizon glass, the eye is then to be applied to the upper hole in the sight vane; otherwise, to the lower hole: and, in this case, the quadrant is to be held so that the sun may be bisected by the line joining the silvered and transparent parts of the glass. The moon is to be kept as nearly as possible in the same position, and the image of a star is to be observed in the silvered part of the glass, adjacent to the line of separation of the two parts.

There are two different methods of taking observations with the quadrant. In the first of these the face of the observer is directed towards that part of the horizon immediately under the sun; and is therefore called the *fore observation*. In the other method, the observer's face is directed to the opposite part of the horizon, and consequently his back is towards the part under the sun, and is hence called the back observation. This last method of observation is to be used only when the horizon under the sun is obscured, or rendered indistinct by fog, or any other impediment.

This quadrant was first proposed by Newton, but improved, or perhaps reinvented, by Hadley. Its operation depends on the effect of two mirrors, which bring both the objects of which the angular distance is to be measured at once into the field of view; and the inclination of the speculums by which this is performed serves to determine the angle. The ray proceeding from one of the objects is made to coincide, after two reflections, with the ray coming immediately from the other, and since the inclination of the reflecting surfaces is then half the angular distance of the objects, this inclination is read off on a scale in which every actual degree represents two degrees of angular distance, and is marked accordingly. There is also a second fixed speculum placed at right angles to the moveable one, when in its remotest situation, which then produces a deviation of two right angles in the apparent place of one of the objects, and which enables us, by moving the index, to measure any angle between 80° and 90°.

This operation is called the back observation; it is however seldom employed, on account of the difficulty of adjusting the speculum for it with accuracy. The reflecting instrument, originally invented by Hooke, was arranged in a manner somewhat different.

FLOATING COLLIMATOR.

A paper by Capt. H. Kater, was read on the 13th January, before the Royal Society, entitled "*A Description of a Floating Collimator.*

This instrument is destined to supply the place of a level or plumb-line in astronomical observations, and to furnish a ready and perfectly exact method of determining the position of the horizontal or zenith point on the limb of a circle or zenith sector. Its principle is the invariability, with respect to the horizon, of the position assumed by any body of invariable figure and weight floating on a fluid. It consists of a rectangular box containing mercury, on which is floated a mass of cast iron, about twelve inches long, four broad, and half an inch thick, having two short uprights or Y's of equal height, cast in one piece with the rest. On these is firmly attached a small telescope, furnished with cross wires, or, what is better, crossed portions of the fine balance spring of a watch, set flat-ways, and adjusted *very exactly* in the sidereal focus of its object-glass. The float is browned with nitric acid to prevent the adhesion of the mercury, and is prevented from moving laterally by two smoothly polished iron pins, projecting from its sides in the middle of its length, which play freely in vertical grooves of polished iron in the sides of the box. When this instrument is used, it is placed at a short distance from the circle whose horizontal point is to be ascertained, on either side (suppose the north) of its centre, and the telescopes of the circle and of the collimator are so adjusted, as to look mutually at each other's cross wires (in the manner lately practised by Messrs. Gauss and Bessel), first of all coarsely, by trial, applying the eye to the eye-glasses of the two instruments alternately, and finally by illuminating the crosss wires of the collimator with a lantern and oiled paper, (taking care to exclude false light by a black screen having an apperture equal to that of the collimator,) and making the coincidence in the manner of an astronomical observation, by the fine motion of the circle. The microscopes on the limb are then read off, and thus the apparent zenith distance of the collimating point (intersection of the wires) is found. The collimator is then transferred to the other (south) side of the circle, and a corresponding observation made *without reversing the circle*, but merely by the motion of the telescope on the limb. The difference of the two zenith distances so read off is double the error of the zenith or horizontal point of the graduation, and their semi sum is the true zenith distance of the collimating point, or the co-inclination of the axis of the collimating telescope to the horizon.

By the experiments detailed in Captain Kater's paper, it appears that the error to he feared in the determination of the horizontal point by this instrument, can rarely amount to half a second if a mean of four or five observations be taken. In a hundred and fifty one single trials, two only gave an error of two seconds, and one of these was made with a wooden float. In upwards of a hundred and twenty of these observations, the error was not one second.

ROPE BRIDGES IN INDIA.

These bridges are called Portable Rustic Bridges of Tension and Suspension, and they are exactly what the name describes. A few hackeries will carry the whole materials, and the appearance of the bridge is rustic and picturesque. They are distinctly bridges of tension and suspension, having no support whatever between the extreme points of suspension independent of the standard piles, which are placed about fifteen feet from the banks of the nullah, or river, except what they derive from the tension, which is obtained by means of purchases applied to a most ingenious combination of tarred coir ropes of various sizes, lessening as they approach the centre. These form the foundation for the pathway, and are overlaid with a light split bamboo framework. The whole of this part of the fabric is a fine specimen of ingenuity and mathematical application. One great advantage it possesses is, that if by any accident one of the ropes should break, it might be replaced in a quarter of an hour, without any injury to the bridge. It is impossible in this article to give so particular a description as to render its minute parts clear, nor in fact can any description do so unaccompanied by the plan.

The chief principle of its construction is the perpendicular action of its weight, a principle obviously of paramount necessity in this country, where the soil is so loose, and offers so little resistance—and more particularly in relation to the specific purpose for which they were invented. The whole weight of the bridge, therefore, resting on two single points, so far separated, and unassisted either by pier-head or abutment, rendered its construction a matter of extreme delicacy, and it has been effected in a manner reflecting the highest credit on the genius of the inventor. The combination of lightness with security, and the adaptation, to the utmost nicety, of the required proportionate strength to the parts, forms its chief characteristics. The tension power is wholly independent of the suspension.

The bridge which was placed during the last rains over the Berrai torrent was 160 feet between the points of suspension, with a road-way of nine feet, and was opened for unrestricted use, excepting heavy loaded carts. The mails and banghees passed regularly over it, and were by its means forwarded when they would otherwise have been detained for several days. The last rainy season was the most severe within the last fifty years, and yet the bridge not only continued serviceable throughout, but on taking it to pieces it was found in a perfect state of repair. The bridge intended for the Caramnassa is 320 feet span between the points of suspension, with a clear width of eight feet. It is in other respects the same as the Berai torrent bridge. A six-pounder passes over with ease; six horsemen also passed over together, and at a round pace, with perfect safety.

We have no doubt but that these bridges will eventually become general. During the rains there will be three of them on the great military north-west road to Benares, and we feel satisfied their utility will be finally established at the conclusion of the season.—*Calcutta John Bull.*

RAIL-ROADS—LOCOMOTIVE STEAM ENGINES.

On the 17th instant, a grand experiment as to the power of locomotive engines was performed at Killingworth Colliery, near Newcastle-upon-Tyne, in presence of several gentlemen from the committees of the intended Manchester and Liverpool and Birmingham and Liverpool rail-road companies—when the result was as follows: The engine being one of eight-horse power, and weighing, with the tender (containing water and coals), five tons and ten hundred weight, was placed on a portion of rail-road, the inclination of which, in one mile and a quarter, was stated by the proprietor, Mr. Wood, to be one inch in a chain, or one part in 792: twelve waggons were placed on the rail-road, each containing two tons, and between 13 and 14 hundred weight of coals—making a total useful weight of 32 tons and 8 cwt. The twelve waggons were drawn one mile and a quarter each way, making two miles and a half in the whole, in forty minutes, or at the rate of $3\frac{3}{4}$ miles an hour, consuming four pecks and a half of coals. Eight waggons were then drawn the same distance in thirty-six minutes, consuming four pecks of coals; and six waggons were drawn over the same ground in thirty two minutes, consuming five pecks of coals. Our correspondent also mentions, that the engine must be supplied with hot or boiling, and not with cold water; and that two hundred gallons of water will take the engine 14 miles, at the end of which the supply must be renewed.

RHABDOLOGICAL ABACUS.

A paper, drawn up by Dr. Gregory, was lately read before the Astronomical Society of London, containing a description of a box of rods, named the *Rhabdological Abacus*, presented to the Society by the family of the late Henry Goodwyn, Esq. of Blackheath. It appears that these rods were invented by Mr. Goodwyn for the purpose of facilitating the multiplication of long numbers of frequent occurrence: they were probably suggested by Napier's Rods, and are, for the purposes which the inventor had in view, a great improvement upon them. The rods, which are square prisms, contain on each side, successively, the proposed number in a multiplicand, and its several multiples up to nine times; and these in the several series of rods are repeated sufficiently often to serve for as extensive multiplications as are likely to occur. Thus if the four faces of one rod contain respectively, once, twice, three times, and four times a proposed multiplicand; another rod will exhibit in like manner two, three, four, and five times the same; a third rod, three, four, five, and six times the same; and so on to *nine;* and in several cases, more rods. The numbers are arranged uniformly upon equal and equidistant compartments; while at a small constant distance to the left of each product, stands the number two, three, four, five, &c. which it represents. Hence, in performing a multiplication, the operator has only to select from the several faces of the rods the distinct products which belong to the respective digits in the multiplier, to place them in due order *above* each other, to add them up while they so stand, and write down their sum, which is evidently the entire product required, and obtained without the labour of multiplying for each separate product, or even of writing those products down. For still greater convenience, the rods may be arranged upon a board with two parallel projections placed aslant at such an angle as of necessity produces the right arrangement. There are blank rods to place in those lines which accord with a cypher in the multiplier; and the arrangement may easily be carried on from the bottom product upwards, by means of the indicating digits.

DENSITY OF WATER.

An elaborate memoir by Professor Hällström, on the specific gravity of water at different temperatures, and on the temperature of its maximum density, has appeared in the Swedish Transactions for 1823. It is divided into two parts: The first contains a critical discussion of the results, and the methods employed by preceding experimenters: the second, a detail of an extensive course of experiments, instituted by himself, with a view to the more accurate determination of this important but difficult inquiry. The method of experimenting which he regarded as the most accurate, and which he therefore adopted, was to ascertain the weight of a hollow glass globe, very little heavier than water, and about $2\frac{1}{4}$ inches in diameter, in water of every degree of temperature between 0° and 32·5° cent. The errors arising from a dilatation or contraction of the glass, the weight of the atmosphere, &c. were all calculated, and a corresponding correction made. The result was, that water attains its greatest density at a temperature of 4·108° cent. (39·394° Fahr.); and the *limits* of uncertainty, occasioned by the impossibility of ascertaining the dilatation of glass with perfect accuracy, he estimates to be 0·238° (0·428° Fahr.) on either side of this number.

PROF. OERSTED ON A METHOD OF ACCELERATING THE DISTILLATION OF LIQUIDS.

In Gehlen's Journal für Chemie und Physik, i. 277—289, I have related a few experiments which demonstrate that the disengagement of gas in a fluid, resulting from chemical decomposition, never takes place except in contact with some solid body. This principle may without doubt be applied to the disengagement of vapours. If a metallic wire be suspended in a boiling fluid, it instantly becomes covered with bubbles of vapour. Hence it might be concluded, that a large number of metallic wires, introduced into a fluid which we wish to distil, would accelerate the formation of vapours. To prove this opinion, I introduced 10 pounds of brass wire, of one-fifth of a line in diameter, loosely rolled up, into a distillatory vessel containing 20 measures (about 10 pints) of brandy: the result was, that seven measures of brandy distilled over with a heat, which, without the wire, was capable of sending over only four measures.

An expedient similar to this has been long in common use in England. When a steam-boiler has become encrusted with so much earthy matter, that the contained water ceases to boil with rapidity, it is customary to throw in a quantity of the residue obtained from malt, by extracting its soluble portion, and which consists chiefly of small grains of fibres. Here the disengagement of vapour is promoted by the large number of thin and solid particles. — (Tidskrift for Naturvidenskaberne.)

SOLUTIONS OF QUESTIONS.

Quest. 56, (page 16) *answered by* G. G. C.

This question was, by mistake, numbered the same as another at page 400, vol. i.

	£	s.	d.	£	s.	d.
Present value of 50 calves at 21*s*.	£52	10	0			
Interest for 3 years	7	17	6			
				60	7	6
Grazing 50 cal. at 10*s*.	25	0	0			
Wintering 49 cal. at 15*s*.	36	15	0			
	61	15	0			
Interest for 2 years	6	3	6			
				67	18	6
Grazing 48 cattle at 20*s*.	48	0	0			
Wintering 47 do. at 25*s*.	58	15	0			
	106	15	0			
Interest for 1 year	5	6	9			
				112	1	9
Grazing 46 cattle at 30*s*.	69	0	0			
Wintering 45 do. at 40*s*.	90	0	0			
				159	0	0
				399	7	9
Amount of 44 cattle, at £10 10*s* is				462	0	0
Gain by bringing them up				£62	12	3

This question was also answered correctly by the Proposer; but we received a solution which was not correct.

Quest. 57, *answered by* J. D. *Ironmonger-lane.*

Put x and y = the days in which A and B respectively could have done the work, then $\frac{12}{x} + \frac{12}{y} = 1$, and $x^2 + xy = 1000$. In the first, the value of y is $= \frac{12x}{x-12}$; consequently $xy = \frac{12x^2}{x-12}$; if this be substituted for xy in the second, and the result reduced, we obtain this equation $x^3 - 1000x + 12000 = 0$; which being resolved, gives $x = 20$ days, and therefore $y = 30$ days, the time in which each could have done the work.

This question was also answered by Mr. Whitcombe.

Quest. 58, *answered by* Mr. W. Anderson, *Strand.*

$1728 \div (\frac{1}{40})^2 = 1728 \times 1600 = 2764800 \times \cdot 7854 = 3520252$ inches $=$ 55 m. 4f. 104 yds. 2 ft. 4 inches.

This question was also correctly answered by Mr. Harding, Mr. J. Stephens, Mr. J. Taylor, Mr. Whitcombe, and Mr. A. Copcake.

QUESTIONS FOR SOLUTION.

Quest. 60, *proposed by* Mr. W. Taylor, *Hackney.*

A ball descending by the force of gravity from the top of a tower, was observed to fall half the way in the last second of time; required the tower's height, and the whole time of descent?

Quest. 61, *proposed by* Peter Plus, *Portpatrick.*

A hare starts 5 rods before a greyhound, and is not perceived by him till she has been up 34 seconds; she scuds away at the rate of 12 miles per hour, and the dog, on view, makes after at the rate of 20 miles; how long will the course hold, and how far will the dog have run when he overtakes the hare?

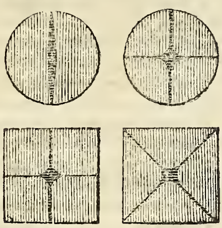
To be solved without using any algebraic characters.

PNEUMATICS.

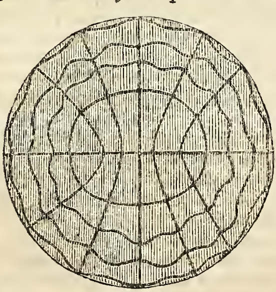
AIR AS THE VEHICLE OF SOUND.

The vibrations immediately dependent on elasticity, are those of rods, plates, rings, and some kinds of vessels, such as drinking glasses. These admit of much greater variety, but they are of more difficult investigation than the vibrations of chords; we shall therefore notice those only, that seem to have something particular belonging to them.

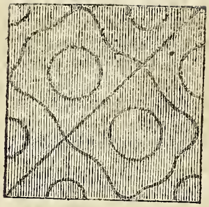
The vibrations of plates may be traced through wonderful varieties, by Professor Chladni's method of strewing dry sand on the plates, which, when they are caused to vibrate by the operation of a bow, is collected into such lines as indicate those parts, which remain either perfectly, or very nearly at rest during the vibrations. Dr. Hooke had employed a similar method, for showing the nature of the vibrations of a bell; and it has sometimes been usual, in military mining, to strew sand on a drum, and to judge by the form in which it arranges itself, of the quarter from which the tremours produced by countermining proceed. The following are specimens of the simplest manner in which sand is collected into lines, on a plate of glass or metal, which is made to sound by means of the bow of a violin.



The following figure represents a round plate performing some of its most complicated vibrations, the lines of division being indicated by the place of the sand.



The following is a representatiou of a square plate, divided into a diversity of vibrating portions.



The vibrations of rings and of vessels are nearly connected with those of plates, but they are modified in a manner which has not yet been sufficiently investigated. A glass or a bell divides in general into four portions vibrating separately, and sometimes into six or eight; they may be readily distinguished by means of the agitations excited by them in a fluid contained in the glass. It is almost unnecessary to observe, that the fluid thus applied, by adding to the mass of matter to be moved, makes the vibration slower, and the sound more grave.

In some cases the vibrations of fluids and solids are jointly concerned in the production of sound: thus, in most of the pipes of an organ denominated reed pipes, the length of a tongue of metal is so adjusted, as to be capable of vibrating in the same time with the air contained in the pipe. Sometimes, however, the air only serves to excite the motion of the solid, as in some other organ pipes, which are usually much shorter than would be required for producing the proper note alone, and probably in the glottis, or organ of the voice of animals. On the other hand, the alternate opening and shutting of the lips, in blowing the trumpet or French horn, can scarcely be called a vibration, and the pitch of the sound is here determined by the properties of the air in the pipe only. The vibrations of a solid may be excited by an undulation propagated through a fluid; thus, when a loud sound strikes against a chord, capable of vibrating, either accurately, or very nearly, with the same frequency, it causes a sympathetic tone, resembling that from which it originated; and the chord may produce such a sound, either by vibrating as a whole, or by dividing itself into any number of equal parts. Thus, if the damper be raised from any of the strings of a harpsichord, it may be made to vibrate, by striking or singing any note, of which the sound corresponds, either to that of the whole string, or to that of any of its aliquot parts. Sometimes also, two chords that are very nearly alike, appear, when sounding together, to produce precisely the same note, which differs a little from each of those which the chords would produce separately; and a similar circumstance has been observed with respect to two organ pipes placed near each other. In these cases, the vibrating substances must affect each other through the medium of the air, nearly in the same manner as two clocks, which rest on the same support, have been found to modify each other's motions, so as to exhibit a perfect coincidence in all of them.

When sounds of different musical strings are compared, a certain difference between them is perceived by the ear, which is called *difference of tone;* and this difference is also expressed by saying, that the one sound is graver, and the other more acute; the variations of tone are found to have a constant or fixed relation to the comparative celerities of vibration.

As the string performs more vibrations in a given time, the sound it yields becomes more acute, and as it vibrates more slowly, the sound is graver. This is easily brought to the test of experiment. The strings that vibrate faster, either from the greater tension, or their smaller length and weight, invariably produce sounds that are more acute, &c.

If eight strings be such, that the numbers of the vibrations they perform in a given time, are as the numbers 24, 27, 30, 32, 36, 40, 45, 48, the sounds of the first seven will be perceived, as increasing in acuteness one above another, from the first to the last, and will yield the notes from the combinations of which all musical effects are produced.

The tone is not affected by the extent of the vibrations, but merely by their time. The loudness of the sound is supposed to depend on the greater extent of the vibrations. Noise and discordant sounds arise from a want of isochronism of vibration. When the vibrations are isochronous, or all performed in the same time, the sounds are always musical.

The last of the strings will sound what is called the *octave* above the first, and the same series may be repeated again between the numbers 48 and its double 96, and each note will be an octave above its corresponding note in the first interval; the numbers of vibrations will be 54, 60, 64, 72, 80, 90, 96; and it is evident that this series may be continued, either up or down, without limit.

The musical scale thus formed, is called the *diatonic scale*.

The pleasure derived from the successive or simultaneous perception of the sounds of this series, appears to be an ultimate fact that can be no farther analysed, but must be referred to the original constitution of the mind. The selections of the combinations of these notes, capable of affording high degrees of pleasure, is the object of the musical art.

The number of vibrations performed in a given time by any sonorous body, may be determined by comparing its sound with the note that is sounded by a musical string of a given length, weight, and tension. The ear is sufficient to decide what string in a harpsichord is in unison with the given sound. The number of vibrations performed in a given time by the former, is equal to the number of those performed in the same time by the latter.

All musical sounds are computed to be contained within ten octaves; so that the number of vibrations in a given time that yields the gravest note, is to that which yields the most acute, as 1 to 2^{10}, or as 1 to 1024.

OF WIND.

The principal cause of those currents of air, to which we give the name of winds, is the disturbance of the equilibrium of the atmosphere, by the unequal distribution of heat.

The air or atmosphere which surrounds the earth is a fluid, possessing, in a remarkable degree, the property of being greatly expanded or rarefied by heat, and condensed by cold. Therefore, when any portion of the air is heated, whether by a natural or artificial cause, it becomes rarer, and consequently ascends to the higher parts of the atmosphere: the cool and dense air then rushes in to restore the equilibrium, and the air at the surface moves from the poles towards the equator. The only supply for the air thus constantly abstracted from the higher latitudes, must be produced by a counter-current in the upper regions of the atmosphere, carrying back the air from the equator toward the pole. The quantity of air tansported by these opposite currents, is so nearly equal, that the average weight of the air, as measured by the barometer, is the same in all places of the earth.

If the surface of the earth were wholly covered with water, so that there was no part of it more disposed than another to obstruct the motion of the air, or that had a greater capacity than another, of acquiring or communicating heat, the air would probably circulate continually in this manner from the poles to the equator, and back again, without any irregularity whatsoever.

In consequence of the rotation of the earth on its axis, another motion is combined with that of the currents just described. The air, which is constantly moving from points where the earth's motion on its axis is slower, to those where it is quicker, cannot have precisely the same motion eastward with the part of the surface over which it is passing, and therefore must, relatively to that surface, describe a curve, having its convexity turned to the east. The two currents, therefore, from the opposite hemispheres, when they meet toward the middle of the earth, have each acquired an apparent motion westward, and as their opposite motions from south and north must destroy one another, nothing will remain but this motion, by which they will go on together, and form a wind blowing directly from the east.

This is the cause of the *trade wind*, which, (with certain exceptions) blows continually between the tropics, or rather between 30° on the one side of the equator, and 30° on the other.

The trade wind declines somewhat from due east toward the parallel to which the sun is vertical at different seasons of the year. As the sun approaches the southern tropic, the trade wind is directed somewhat to the south; and as he approaches the northern, somewhat to the north.

The cause usually assigned for the trade wind, is the constant motion toward the west of the spot to which the sun is vertical, and where of course the rarefaction is greatest. This, it is supposed, draws along with it the air from the east. This, however, is by no means satisfactory; and it seems certain, that if the trade wind were produced in this way, it must have a great rapidity, in place of being a gentle breeze, at the rate of seven or eight miles an hour.

The opinion that the trade wind is produced by the air in its motion southward, falling back toward the west, is mentioned, but rejected, by Halley. It has since been espoused by Franklin and La Place, and is, on the whole, less objectionable than any other.

The matter is here stated somewhat differently from what is done by those authors, particularly the effect of the currents from the opposite hemispheres, in determining the motion to be wholly from the east.

The attractions of the sun and moon have sometimes been considered as among the general causes of the winds. They have, no doubt, a tendency to produce in the atmosphere an undulation backwards and forwards, like the tides which they cause in the ocean. It does not appear, however, that they could produce any continued progressive motion of the air, similar to that of the trade winds. Their effects also are too minute to be perceived, amid the action of so many more powerful causes.

The superior current above described restores the air carried from the higher latitudes to the lower with such a degree of equality, that the average weight of the atmosphere, as measured by the barometer, is nearly the same in all climates. This restoration is, however, subject to great local and temporary irregularities, from the different degrees of resistance that the air meets with in passing over the surface, and the different capacities of that surface for receiving and communicating heat.

The motion of the inferior and superior currents may be seen exemplified on opening a door between two apartments of different temperatures. The flame of a candle near the ground will show the stream that sets from the colder room to the warmer; near the top it will indicate a stream in the opposite direction. As the average quantities of the air carried by these opposite currents are equal, the surface that separates them is probably not far different from that at which the barometer would stand at 15 inches, or half its medium height, at the surface.

If we suppose the mean temperature to be 32°, this elevation will be found = 3010 fathoms, or 18,060 feet = 3·425 miles; which is not so high as the summits of the Cordilleras.

The upper stream in each hemisphere being directed to one point, namely, the pole of that hemisphere, there must arise a considerable condensation and acceleration of the air, as the currents approach that point; and hence the causes of irregular winds must be increased on approaching the poles.

The general direction of the upper current must be to the westward; for the same reason that that of the lower was toward the east.

The trade wind itself is subject to certain irregularities. As the sun advances into the northern hemisphere, the trade wind becomes irregular; and about the middle of April, in all the tract between Africa and the Peninsula of India, and much beyond, changes from north-east to south-west, and continues to blow in that direction till the sun returns to the southern hemisphere.

The cause of this change is difficult to be assigned. It seems probable that, by the sun's entry into the northern hemisphere, he communicates great heat to the sandy deserts of Africa, which lie to the west or south-west of the seas just mentioned. The great heat acquired by the sand of those deserts produces a rarefaction in the columns of air incumbent upon them, and consequently a tendency, in the columns that are near them, and more moderately heated, to flow in and displace the heated air. The air of the Atlantic is most likely to do this; and in passing over Nigritia, &c., to acquire a velocity that carries it on eastward through the Indian ocean.

These periodical winds are called *Monsoons*.

The change, or the setting in of the monsoons, does not happen all at once.

In some places the shifting of the wind is accompanied with calms; in others, with variable winds, heavy rains, thunder, and violent storms.

The tract from the parallel of 30° to the pole, in each hemisphere, is the region of variable winds; and their unsteadiness and violence seem to increase the nearer they approach the polar circles.

The irregularity of winds proceeds from inequalities in the motion of the general currents above-mentioned, and from a variety of local causes; also from the chemical changes that are carried on in the air; such as the solution and precipitation of moisture, and the action of the electric fluid on the different gases which compose the atmosphere.

Sudden and strong gales of wind appear most always to arise from a diminution of the weight of the air in the tract where the wind prevails; and are accompanied or preceded by a fall of the barometer.

Notwithstanding these irregularities, there is in most countries a tendency to periodical winds more or less remarkable, according to the steadiness of the climate. Even with us, where an insular situation, with a great continent on one side, and a great ocean on the other, unites all the causes of a variable climate, the east wind usually prevails in the spring, from the vernal equinox to the summer solstice, and beyond it; during the rest of the year, the westerly winds prevail, though not without frequent incursions of the east; by which our most unpleasant weather is always produced.

The *Etesian*, or northerly wind, prevails very much in summer all over Europe. Pliny describes it as blowing regularly in Italy for forty days after the summer solstice, lib. ii. cap. 47. It is part of the great current that carries the atmosphere of the higher latitudes down to the tropical regions.

The velocity of the wind varies from one that is hardly sensible to one of 100 miles in an hour.

The velocity of wind may be estimated by the velocity of clouds, or of light bodies carried by it.

PERSPECTIVE.

Having given a comprehensive and popular view of the beautiful and interesting science of Optics, we shall now introduce an equally beautiful and useful branch of natural philosophy—that is, Perspective. This may be considered as a continuation of Optics, its fundamental principles being derived from that science, while its application is regulated by laws purely geometrical.

But though a correct knowledge of geometry is indispensably necessary to the acquirement of a complete knowledge of the practical part of perspective, we shall endeavour to convey a knowledge of the elementary and most useful part of this art, to those who have made but small progress in the study of Geometry.

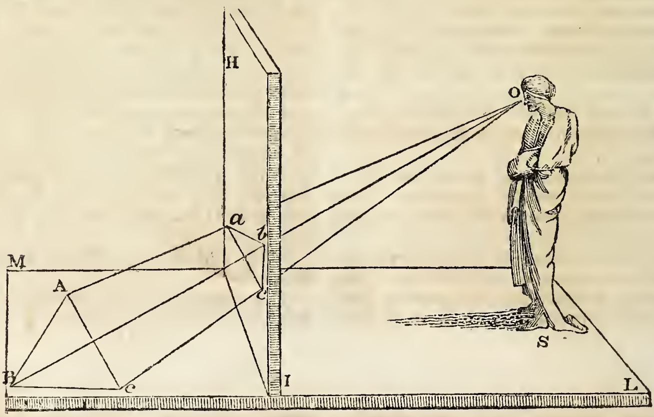
Perspective is the art of delineating visible objects upon a plane surface, so that the figure drawn may represent the same form and position, which the object holds in nature, or, as it would be found to be represented upon the retina, in the bottom of the eye.

Perspective is usually divided into two branches, *linear* and *aerial.*

Linear Perspective regards the position, magnitude, form, &c. of the several lines or colours of objects, and the manner of exhibiting their diminution. It is, therefore, the mathematical part of perspective.

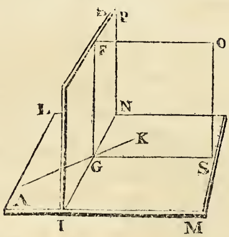
Aerial Perspective is that which regards the colour, lustre, strength, boldness, &c. of distant objects, considered as viewed through a column of air; it therefore forms an important part of the art of painting.

Linear Perspective: suppose a glass plane, as



H I raised perpendicular on an horizontal plane; and the spectator S directing his eye O, to the triangle A B C: if now we conceive the rays A O, O B. O C, &c. in their passage through the plane, to leave their traces or vestigia, in *a*, *b*, *c*, &c. on the plane; there will appear the triangle *a b c*, which, as it strikes the eye by the rays *a* O, *b* O, *c* O, by which the species of the triangle A B C is carried to the same; it will exhibit the true appearance of the triangle A B C, though the object should be removed; the same distance and height of the eye being preserved. The business of *perspective*, then, is to show by what certain rules the points *a b c*, &c. may be found geometrically: and hence also, we have a mechanical method of delineating any object very accurately.

In delivering the general laws of this branch of study, it is necessary to premise the following properties of a right line; namely, That the appearance of a right line is ever a right line, whence the two extremes being given, the whole line is given. That if a line F G, as represented in the following figure,



be perpendicular to any right line N I drawn on a plane, it will be perpendicular to every other right line through the same point G, drawn on the same plane. That the height of the point appearing on a plane, is to the height of the eye, as the distance from the objective point from the plane, to the aggregate of that distance, and the distance of the eye.

Besides these elementary observations, it is necessary we should subjoin the following *definitions*, respecting the various planes, &c. referred to when treating of Perspective.

DEFINITIONS.

1. The plane on which the representation, projection, or picture of any object is drawn, is called the *perspective plane*, and also the plane of the picture. It is supposed to be placed between the eye and the object.

2. The point of sight is that point from which the picture ought to be viewed. This point is also called the point of view.

3. If from the point of sight, a line be drawn at right angles to the picture or perspective plane, the point in which it meets that plane is called the centre of the picture; and the distance between that centre and the point of sight, or the perpendicular above mentioned, is called the *distance of the picture.*

4. By original object, is meant the real object placed in the situation it is represented to have by the picture.

5. By original plane, is meant the plane on which any original point, line, or plane figure, is situated.

6. The point in which any original line, or any original line produced, cuts the perspective plane, is called *the intersection* of that line.

7. The line in which any original plane cuts the perspective plane, is called the intersection of that original plane. If the original plane be that of the horizon, its intersection with the picture, or the line above mentioned, is called the *ground line.*

8. The point in which a straight line drawn through the point of sight parallel to any original line cuts the picture, is called the vanishing point of that original line. And the distance between that point and the point of sight, is simply called the *distance* of that vanishing point.

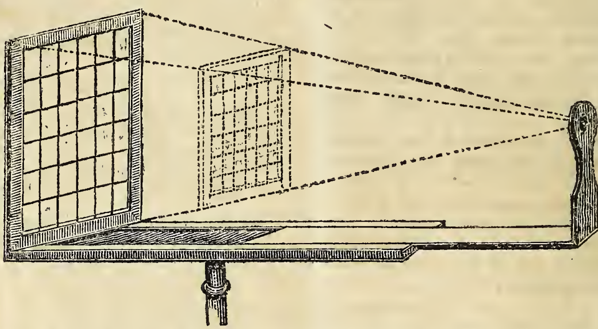
9. The line in which a plane drawn through the point of sight parallel to any original plane cuts the perspective plane, is called the *vanishing* line of that original plane. If from the point of sight there be drawn a line cutting that vanishing line at right angles, the point of intersection is called the centre of the vanishing line. And the distance between the point of sight and that point or centre, is called simply the *distance* of the vanishing line.

10. If from a given point, a straight line be drawn at right angles to any plane, the point of intersection is called the seat or orthographic projection of the given point on that plane. And if from all the points of any line or plane figure perpendiculars be drawn to any plane, the line or figure formed by their intersections with it, is called the seat or orthographic projection of the given line or figure on that plane.

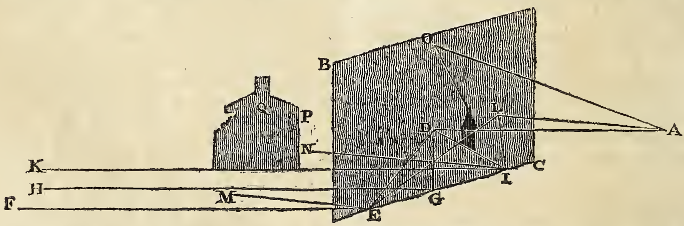
Previous to giving rules for delineating objects according to the established laws of perspective, we shall show how this may be done in a mechanical manner, by means of a frame with cross threads or wires, interposed between the eye and the object. The eye is to be applied to an aperture, which must be fixed, in order to preserve the proportions of the picture; and which must be small, in order that the threads and the more distant objects may be viewed at the same time with sufficient distinctness. The paper being furnished with corresponding lines, we may observe in what division of the frame any conspicuous point of the object appears, and may then represent its image by a point similarly situated among the lines drawn on our paper; and having obtained in this manner a sufficient number of points, we may complete the figures by the addition of proper outlines.

Sometimes, for the delineation of large objects requiring close inspection, it has been found useful to employ two similar frames, the one a little smaller than the other, and placed a certain distance from it, so that every part of the object, when seen through the corresponding divisions of both frames, appears in the same manner as if the eye were situated at a very remote point.

The following figure represents an instrument of this kind. The dotted lines show how a second frame may be applied instead of the sight, so as to answer the same purpose.

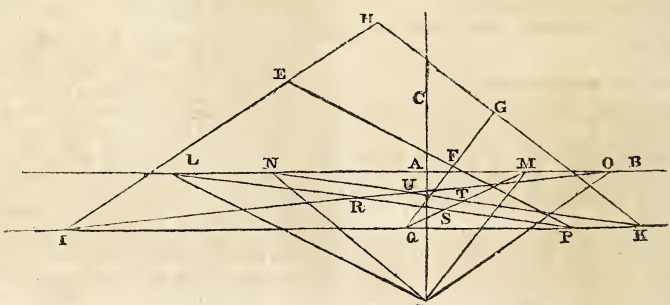


Having now shown the nature of perspective drawing, and given a number of definitions, in order to render the subject as intelligible as possible, we shall next attempt to illustrate the principles of this art, by showing how any object may be represented upon a plane, as it actually appears in nature.



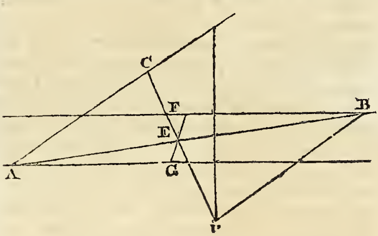
A being the place of the eye, and B C the plane of projection, if A D be parallel to E F, G H, and I K, D will be their vanishing point, and E D, G D, and I D, their whole images: A L being parallel to E M and I N, L will be their vanishing point, and E L, I L their whole images: and A O being parallel to P Q, O will be its vanishing point.

Let A be the centre of the picture represented by the following figure.



A B the horizontal vanishing line, A C the vertical line, and D the point of distance, if a ground plane E F G H of any figure on the horizontal plane be placed in its true position with respect to I K, the bottom of the picture, the vanishing point of all its lines will be found, by drawing D L, D M, D N, and D O parallel to those lines respectively; and the whole images of the lines will be P L, Q M, K N, and I O, determining by their intersections the figure R S T U, which will be the projection of E F G H. The plan may also be drawn in an inverted position, below the line I K, and the point of distance taken above A, instead of below it.

In order to find the position of the image of a given point of a line, we must divide the whole image in such a manner, that its parts may be to each other, in the same proportion as the distance of the given point, and of the eye, from the plane of projection. This may be readily done, when a ground plan has been first made, by drawing a line from any point in the plan, to the point of distance, which will cut the whole image of the line in the point required, as in the following figure: A B, being the whole image of the line represented by A C as a ground plan, and D



the point of distance, we may find E the image of the point C, by drawing C D; or we may make B F = B D, and A G = AC, F G will then also cut A B in the point E.

CHEMISTRY.

SILVER.

Silver is a very good conductor of electricity and galvanism. It has no sensible taste nor smell; neither does it produce any effect upon the animal economy; and though it cannot be considered as dangerous to the health, it must, nevertheless, be reckoned amongst the number of perfectly inert substances, destitute of any medicinal property.

Nature presents silver neither in such abundance, nor in so many places, nor in such large masses, as most of the other metallic substances. Even the number of species that can be distinguished amongst the ores of this metal is infinitely more limited than those which are admitted in most of the other metals. The mineralogists, who have hitherto considered its varieties as species, have moreover committed another error; namely, that of having too closely followed the errors and prejudices of the miners. These, considering as ores of silver all those ores that are capable of affording this precious metal, of whatever nature they may be, which have very much obscured the natural history of this metal.

Pure silver, when exposed to the air, remains in it without alteration, except with respect to its polish and brilliancy; it becomes less shining and a little tarnished at its surface, but without being oxidized. We ought not, however, to confound the kind of covering or stratum of a deep blue colour, which is formed upon old silver plate exposed for a long time to the contact of several gases mixed with the air; with a stratum which, according to the examination of it instituted by Mr. Proust, as merely a sulphuret of this metal. Silver has long been believed to be perfectly indestructible by the contact of the air, even when aided by a very intense heat; and on this account it was ranked amongst the perfect metals. Several Chemists, and especially Junker, had advanced, that by treating silver by a long reverberation, and in a furnace where the flame circulated above the metal, the silver was at last converted into a vitriform oxide. It has even been added, that when united with mercury, and divided by this liquid metal, it was oxidized by the processes which are usually employed for converting mercury into red oxide, and which is not improbable.

Many experiments made since the assertion of Junker, and by different processes, have proved that silver is really oxidizable, but only that it is much less so, and with much greater difficulty, than the other metals. Macquer was the first who remarked this oxidation, by exposing silver in a crucible to the intense heat of the furnace of Sevres twenty successive times. At the last time, very sensible traces of oxidation were perceived, and a vitrification of an olive colour. Macquer never failed to observe, when treating silver in the focus of a burning glass, that after a long incandescence, it became covered with a white powder, which formed a stratum upon the support of the silver. Homberg, in the first experiments with the burning glass of Tchirshausen, had made the same observations upon silver and upon gold. It cannot be doubted that these facts indicate a marked oxidation of the silver, and that they become more strong and conclusive when joined with the experiments which we shall mention.

Van Marum made many valuable researches respecting the effects of electricity with the grand machine of Teyler, and found that it took fire and burned. By passing the electric shock from a battery through a wire of this metal, the wire is suddenly reduced, as it were, into powder, with a greenish white flame, which passes with the rapidity of lightning, and the oxide manifestly formed in this operation is dissipated in smoke. If we perform the same operation by wrapping up the wire, or fixing it upon white paper, it attaches itself to it in a very fine powder of a greenish grey colour, so fine and so adherent, that it resembles smoke, or a light covering which cannot be separated from it again. It is impossible here to doubt either of the state of oxidation of the silver, or of its combustiblity; because the phenomenon is constantly accompanied with flame. We may attribute this effect, which is not produced by ordinary fire, however intense it may be, to the extreme division of the metal by the electric shock, and to the high temperature produced by the electric composition in the body which is exposed to it. A stroke of lightning upon silver wires and silver furniture, produces exactly the same phenomena, and is followed by the same results.

The oxide of silver formed by these different processes, and which is so difficult to be obtained, is likewise extremely easy of reduction, because the silver adheres to the oxygen very weakly. Though the presence of this body augments its weight, changes its properties, and especially renders it acrid and caustic, nothing more is required than to expose these greenish or yellowish grey oxides to the contact of the solar rays, in order to make them assume a darker colour, become black, and approach to the metallic state. When we heat them in close vessels, and with the pneumatic apparatus, we obtain from them pure oxygen gas, and easily convert them into the brilliant and ductile metal, by fusing them in a crucible.

Neither carbon nor hydrogen have been combined with silver; but it combines readily with sulphur and phosphorus.

It is well known, that when silver is long exposed to the air, especially in frequented places, as churches, theatres, &c. it acquires a covering of a violet colour, which deprives it of its lustre and malleability. This covering, which forms a thin layer, can only be detatched from the silver by bending it, or breaking it in pieces with a hammer. It was examined by Mr. Proust, and found to be *sulphuret of silver.*

Silver does not combine with the simple incombustibles.

Silver combines readily with the greater number of metallic bodies.

When silver and gold are kept melted together, they combine, and form an alloy, composed, as Homberg ascertained, of one part of silver and five of gold. He kept equal parts of gold and silver in gentle fusion for a quarter of an hour, and found, on breaking the crucible, two masses, the uppermost of which was pure silver, the undermost the whole gold combined with $\frac{1}{6}$ of silver. Silver, however, may be melted with gold in almost any proportion; and if the proper precautions be employed, the two metals remain combined together.

The alloy of gold and silver is harder and more sonorous than gold. Its hardness is a maximum when the alloy contains two parts of gold and one of silver. The density of these metals is a little diminished, and the colour of the gold is much altered, even when the proportion of the silver is small; one part of silver produces a sensible change in twenty parts of gold. The colour is not only pale, but it has also a very sensible greenish tinge, as if the light reflected by the silver passed through a very thin covering of gold. This alloy, being more fusible than gold, is employed to solder pieces of that metal together.

When silver and platinum are fused together, (for which a very strong heat is necessary,) they form a mixture, not so ductile as silver, but harder and less white. The two metals are separated by keeping them for some time in the state of fusion; the platinum sinking to the bottom from its weight. This circumstance would induce one to suppose, that there is very little affinity between them. Indeed, Dr. Lewis found, that when the two metals were melted together, they sputtered up as if there were a kind of repugnance between them. The difficulty of uniting them was noticed also by Scheffer.

OF PALLADIUM.

This metal was first found by Dr. Wollaston combined with platina, among the grains of which he supposes its ore to exist, or an alloy of it with iridium and osmium, scarcely distinguishable from the crude platina, though it is harder and heavier.

Palladium is of a greyish white colour, scarcely distinguishable from platina, and takes a good polish. It is ductile and very malleable; and being reduced into thin slips, is flexible, but not very elastic. Its fracture is fibrous, and in diverging striæ, showing a kind of crystalline arrangement. In hardness it is superior to wrought iron. Its specific gravity is from 10·9 to 11·8. It is a less perfect conductor of caloric than most metals, and less expansible, though in this it exceeds platina.

On exposure to a strong heat, its surface tarnishes a little, and becomes blue; but an increased heat brightens it again. It is reducible *per se*. Its fusion requires a much higher heat than that of gold; but if touched while hot with a small bit of sulphur, it runs like zinc. The sulphuret is whiter than the metal itself, and extremely brittle.

Nitric acid soon acquires a fine red colour from palladium, but the quantity it dissolves is small. Nitrous acid acts on it more quickly and powerfully. Sulphuric acid, by boiling, acquires a similar colour dissolving a small portion. Muriatic acid acts much in the same manner. Nitromuriatic acid dissolves it rapidly, and assumes a deep red.

Alkalis and earths throw down a precipitate from its solutions generally of a fine orange colour; but it is partly re-dissolved in an excess of alkali. Some of the neutral salts, particularly those of potash, form with it triple compounds, much more soluble in water than those of platina, but insoluble in alcohol.

Alkalis acts on palladium even in the metallic state; the contact of air, however, promotes their action.

A neutralized solution of palladium is precipitated of a dark orange or brown colour by recent muriate of tin; but if it be in such proportions as to remain transparent, it is changed to a beautiful emerald green. Green sulphate of iron precipitates the palladium in a metallic state. Sulphuretted hydrogen produces a dark brown precipitate; prussiate of potash an olive coloured: and prussiate of mercury a yellowish white. As the last does not precipitate platina, it is an excellent test of palladium. This precipitate is from a neutral solution in nitric acid, and detonates at about 500° of Fahr., in a manner similar to gunpowder. Fluoric, arsenic, phosphoric, oxalic, tartaric, citric, and some other acids, with their salts, precipitate some of the solutions of palladium.

When strongly heated, its surface assumes a blue colour; but by increasing the temperature, the original lustre is again restored. This blue colour is doubtless a commencement of oxidizement; but neither the properties of the oxides of this metal, nor the proportion of oxygen with which it combines, have been ascertained.

The effect of hydrogen upon palladium has scarcely been tried. Chenevix melted the metal in a charcoal crucible, but it was not in the least altered.

Palladium unites very readily to sulphur. When it is strongly heated, the addition of a little sulphur causes it to run into fusion immediately, and the sulphuret continues in a liquid state till it be only obscurely red hot. Sulphuret of palladium is rather paler than the pure metal, and is extremely brittle. By means of heat and air, the sulphur may be gradually dissipated, and the metal obtained in a state of purity.

Azote has probably no effect upon it; but muriatic acid promotes its oxidizement, and forms a red solution with the oxide.

OF MERCURY.

Mercury, like some other metals, appears to have received its name from the planet, with which it was compared by the Persians, on account of its nature, which was supposed to approach to that of gold, as this planet is nearest to the sun, and has been known since the most remote ages of antiquity. From a comparison of its properties with those of silver, it was long ago termed *quicksilver, hydrargyrum*. In the species of hieroglyphics that were formerly employed for representing bodies, mercury was represented by the combined signs of the sun and moon, or of gold and silver, linked together, and supported upon a cross.

The alchemists have laboured much upon this metal. They considered it as very much resembling gold and silver, and differing but very little from them; they imagined that it wanted but very little to become either the one or the other, and they always hoped to discover the means of transmuting it into these metals. Some of them have even affirmed, that they had succeeded in effecting this transmutation. These adepts agree with each other, that it is much more easy to convert it into silver than into gold. According to them, in order to convert it into silver, nothing more is required than to fix it. It was, therefore, in this fixation of mercury that they made all the art of their opus magnum, all the marvellous part of their science to consist; this was the grand object of their attention, and the scope of all their wishes. All these pretensions, however, are not supported by a single well-attested fact: and the more we advance in the study of the properties of mercury, the more differences we find between it and the metals to which it has been supposed to approach the nearest.

The most celebrated philosophers, and the most able chemists, have all successively occupied themselves with this metal: they have endeavoured to ascertain all its properties with more or less precision; and the use which has been made of it since the end of the last century, or since the time of Boyle, in the construction of a great number of philosophical instruments, has afforded frequent occasion for investigating and examining its different characters. It is in this manner that its weight, its phosphorescence, its dilatibility, its volatility, its alterability, its mobility, &c. have been successively ascertained.

The application of the pneumatic chemistry has connected together all the known facts relative to the chemical properties of mercury; it has given rise to the discovery of a considerable number of new ones; it has elucidated a great number of facts which before could not be explained; it has drawn from oblivion several which were neglected, or in a manner abandoned; it has dissipated all the obscurity, ambiguity, or uncertainty that remained in the enunciation of its properties; it has conducted Chemists to several important discoveries: such as the mutual differences between the greater part of the metallic or mercurial salts; the comparative state of the different oxides of mercury; the action of each oxide upon this metal or its oxides; the formation of several triple salts; the cause of the energy and causticity of the mercurial salts or oxides; the spontaneous reduction of these oxides; their decompositions by some of the metals; the nature and characters of several precipitates; the different states of some of its solutions; the extinction of mercury in a number of substances, which had always been considered as a simple division, but which, in reality, is a true oxidation. Mercury being one of the most useful of metallic substances for medical purposes, for the arts, and for all those branches of knowledge which extend our views of nature, we shall give a full detail of its properties.

ASTRONOMY.

MOTIONS OF THE EARTH.

When we consider the apparent diurnal motion of all the celestial bodies, we cannot but recognise the existence of one general cause, which produces this appearance. But when we consider that these bodies are not only at different distances from the earth, but at different distances from each other, and that these distances are not always the same, we shall find it difficult to conceive that it is the same cause that produces this appearance on all of them.

The difficulty, however, becomes considerably less when it is recollected, that a person in motion, looking at an object at rest, perceives the same change of position in the object as if he were himself at rest, and the object in motion in the opposite direction. Every one who has looked, for the first time, from the window of a carriage moving quickly along the road; or from the deck of a ship sailing smoothly along the shore; fancies that every thing which the carriage or vessel passes is in motion, and that he is himself at rest.

An appearance still more deceiving takes place, when a person looks out of the cabin window of a ship, in a dark night, at a distant light apparently in motion. For the change of place in the light may arise either from its being really in motion, or on board of another vessel, while the vessel, in which the spectator is, is placed at anchor; or the light may be stationary, and its apparent motion occasioned by the motion of the ship which carries the spectator; or it may even be occasioned by the motion of the vessel which carries the light being quicker or slower than the one which carries the spectator. The difficulty in determining to which of these causes the motion of the light is to be attributed, arises from the want of some intervening object whose state is known, and by which the apparent motion may be compared. Now this is precisely the situation in which we stand with regard to the heavenly bodies. For the motion of the earth on its axis, if it really has such a motion, must be incomparably smoother than any vessel or machine made by human art; and as there is no fixed intermediate object between it and the heavenly bodies, no direct proof of this motion can be obtained.

As far, then, as appearances enable us to judge, either the earth may be at rest, and the heavens carried round it every twenty-four hours, or the heavens may be at rest, and the earth revolve round its axis, in the same time. For the rising and setting of the sun and stars, with all the other celestial phenomena, will be presented in the same order whether the heavens revolve round the earth, or the earth round its axis.

However, on comparing these appearances with others which are more within our reach, and with the established laws of motion, we shall find it is much more probable they are occasioned by the revolution of the earth on its axis, than the revolution of the whole heavens. For as the heavenly bodies present the same appearances to us, whether the firmament carries them round the earth, or the earth itself revolves in a contrary direction, it seems much more natural to admit the latter hypothesis than the former, and to regard the motion of the heavens as only apparent.

The semidiameter of the earth is only about 4000 miles, and consequently its circumference is about 25,000 miles.

This is, therefore, the space every point of its equator must pass through, if the earth revolves on its axis, which is little more than 1000 miles per hour, or about 17 miles per minute. This velocity is certainly very considerable, being nearly equal to that of a cannon-ball when it leaves the mouth of a cannon; but it becomes totally insignificant when compared with the motion of some of the heavenly bodies, required on the other supposition. The distance of the sun from the earth is about ninety-five millions of miles; and therefore if he revolves round the earth in twenty-four hours, he must pass over more than six times this space in the same time, and consequently must move at the rate of about 25,000,000 miles per hour, which is more than 20,000 times quicker than a cannon-ball. The planet Uranus is about twenty times farther distant from the earth than the sun, and consequently the velocity of its daily motion must be twenty times greater. But although these velocities are sufficient to startle the imagination, they are really nothing when compared to the rapidity with which the fixed stars must move to accomplish a revolution round the earth in twenty-four hours. If the distance of the fixed stars be assumed at 200,000 times the distance of the sun from the earth, they must move over the space of 1,400,000,000 miles per second, in order to complete a revolution round the earth in twenty-four hours! This is a degree of velocity of which we can have no kind of conception; and yet, if we consider the velocity which those stars must have that are many thousands of times more distant from the earth, it must be almost infinitely greater. If we, therefore, take into consideration the number of bodies that must move, and the prodigious rapidity of their motions, to produce the same appearances which the revolution of one body, with a comparatively moderate velocity, can produce, we shall scarcely hesitate a moment in concluding that the motion of this one body is the true cause of these appearances.

This conclusion must appear still more obvious when we attend to the comparative bulk of these different bodies. Of the planets which belong to the solar system, three of them are known to be much greater than the earth; Jupiter being nearly fifteen hundred times; Saturn nine hundred times; and Uranus eighty times. But the sun exceeds them all in magnitude, being considerably more than a million of times greater than the earth. Our ignorance of the real distances of the fixed stars prevents us from ascertaining correctly their real magnitudes; but, from what we know of their distances, we are entitled to conclude that they are at least equal in size to the largest of the planets. If such, therefore, be the magnitude of these bodies, how inconsistent would it be with every idea of order and arrangement to suppose, that such a vast number of immense bodies daily revolve round such a little and comparatively insignificant body as the earth! What extraordinary power would be necessary to retain them in their orbits, and counterbalance the amazing centrifugal force which they must possess! The idea, too, of so many immense and independent bodies, so vastly distant from the earth and from each other, performing their revolutions round this little ball, exactly in the same number of seconds, is scarcely to be entertained for a single moment: all the phenomena, especially when supposed to arise from these revolutions, can be satisfactorily and easily accounted for, by supposing the earth to revolve on its axis.

If we suppose the planets to be carried round the earth, from east to west, every twenty-four hours, and also allow them a motion peculiar to themselves from west to east, (which they are observed to have,) we produce such a combination of opposite motions, as has never yet been observed in any of the heavenly bodies, and which it would be impossible to reconcile with any of the known principles of mechanics. But the rotation of a body on its axis, combined with a motion in its curvilineal orbit, is what we are quite familiar with, and what is exhibited by a school-boy by spinning his top.

But one of the strongest proofs of the rotation of the earth is its figure. For it is now well known that the earth is not a perfect sphere: its polar diameter being considerably less than its equatorial.* It is also known that this is the shape which a spherical body would in time assume, if it revolved on a fixed axis; and therefore it is reasonable to conclude that the spheroidical figure of the earth is occasioned by its rotatory motion. This conclusion is supported by the extraordinary fact, that the difference between the polar and equatorial axis of the earth, as deduced from theory alone, is nearly the same as from actual measurement of various arcs of meridian circles.—The same conclusion is farther supported by analogy.

A rotatory motion has been observed in several of the other planets, and from west to east, the direction in which the earth must resolve in order to occasion the apparent diurnal motion of the heavens from east to west. Jupiter, a much larger body than the earth, turns round his axis in less than twelve hours. Now both the earth and Jupiter are known to be flattened at the poles. All these facts, therefore, lead us to conclude, that the earth has really a motion of rotation, and that the

* Some of the objections which have been stated against the rotation of the earth will be noticed in treating of the Ptolemaic and Tychonic systems.

diurnal motion of the heavens is only an illusion produced by this rotation.

The diurnal rotation of the earth being assented to, its annual motion will scarcely be denied; for its similarity to the other planets is considerably strengthened by this circumstance. For the planets being found to revolve on their axis, and to be flattened at the poles like the earth; and being found to have periodical revolutions from west to east, we are led to suppose, that the earth has a *similar* revolution, in order to render the analogy between it and the rest of the planets complete. But the appearances afford us as little assistance in ascertaining the truth of this supposition, as in the case of the diurnal motion; for, whether we suppose the earth to be at rest and the sun to move round it in the ecliptic in the course of a year, or the sun to be at rest and the earth to describe this path in the same time; the phenomena of the seasons, eclipses, and all other appearances connected with the sun's annual motion, may be explained on either hypothesis. But, although this be the case, it is much more probable that these appearances are produced by the annual motion of the earth round the sun, than by the motion of the sun round the earth. For by supposing the earth to move round the sun, we not only give order and simplicity to the solar system, and preserve the analogy, which is so conspicuous among the other bodies which compose that system, but we remove several difficulties which unavoidably attend the opposite hypothesis.—It has already been remarked, that the earth is considerably smaller than several of the other planets, and that it is about fourteen hundred thousand times less than the sun; it is therefore quite inconsistent with every idea of order and arrangement to suppose, that bodies of such extraordinary size should revolve round one of comparatively small magnitude. For, independent of the complication of the planetary motions which such a supposition would introduce, it would overthrow one of the best established principles of mechanics, and is quite inconsistent with the law which is known to subsist between the times of the revolutions of the planets, and their distance from the sun. For the farther they are from the sun, their motion is the slower. Their periodic times of revolution being to each other as the cubes of their mean distances from the sun. Now, according to this remarkable law, the length of a revolution of the earth round the sun, should be exactly a sidereal year. This is therefore an incontestible proof that the earth moves round the sun, like the other planets, and is subject to the same laws. To this we may add, that the aspects of increase and decrease of the planets, the times of their seeming to stand still, and move direct and retrograde, answer precisely with the motion of the earth: but cannot be reconciled with that of the sun, without introducing the most absurd and monstrous suppositions, which would destroy all order, harmony, and simplicity, in the system.

But the most direct proof of the earth's annual motion is derived from the aberration of light. For during the time which light takes to pass over the semidiameter of the earth's orbit, which is 8′ 13″, the earth ought to move 20″·232 in its orbit, and this is found by observations to be actually the case.

The annual as well as the diurnal motion of the earth may, therefore, be considered as completely established. The objections which have been urged against these motions, by the supporters of the Ptolemaic and Tychonic systems of the heavens, will be noticed when treating of these systems.

To the texts of Scripture which seem to contradict the motions of the earth, the following reply may be made to them all. That it is plain from many instances, that the Scriptures were never designed to instruct men in philosophy, but in matters of religion, and are not always to be taken in the literal sense. For Job describes the earth as being *supported* upon *pillars*, and in another place as being hung upon *nothing*; and Moses calls the moon a great luminary, although it is well known to be an *opaque* body, which shines only by reflecting the light of the sun.

It is perfectly certain these expressions were not meant to convey any astronomical opinion; but employed because they would be easily understood by those to whom they were immediately addressed. In familiar discourse, astronomers themselves speak of the sun's place in the ecliptic, of his rising and setting, &c.; for if they did not, they would be under the necessity of explainining their meaning every time they had occasion to mention those appearances.

ON THE CHANGE OF SEASONS.*

The alternate succession of day and night, as well as the variety of seasons, depend entirely on the motions of the earth. For if the sun and the earth were perfectly at rest with respect to each other, it is evident that one half of the earth would always be in the light, and the other half in darkness, as the sun can only enlighten one half of its surface at a

* If a terrestrial globe be placed in the various positions mentioned in this article, it will contribute very much to impress the mind with the true cause of the change of the seasons.

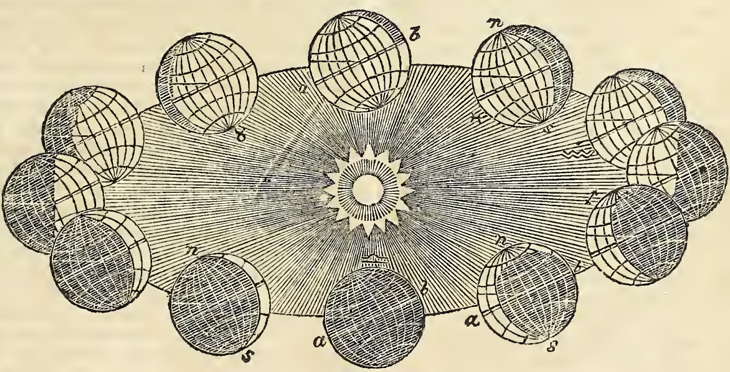
time. But as the earth turns round its axis once in twenty-four hours, any particular place on its surface will pass through light and darkness alternately. As long as it continues in the enlightened hemisphere, it will be day at that place; but while it passes through the opposite hemisphere, it will be night. But although the regular succession of day and night be occasioned by the diurnal revolution of the earth on its axis, yet this motion is not of itself sufficient to produce that variety in the lengths of days and nights, which the various places of the earth experience in the course of a year.

For should it revolve on its axis, with one of its poles always pointed exactly to the sun, one half of the earth would be constantly in the light and the other half in darkness, notwithstanding its rotation. Again, if we suppose the earth to turn on its axis, with its equator directly pointed to the sun, then the light would just reach both poles, consequently all places would be in light and darkness alternately, and the days and nights would be exactly twelve hours each at every part of the globe.

If either extremities of the earth's axis, suppose the northern, were to make an acute angle with an imaginary line joining the centre of the sun with any point of the earth's equator, it would follow that the north pole, and a certain tract round it, would remain always in the light, notwithstanding the revolution of the earth on its axis. Even those places in the northern hemisphere to which the sun appeared to rise and set, would have their days always longer than their nights; at the equator the days and nights would be equal; but in the southern hemisphere the reverse would happen to what took place in the northern. For those places to which the sun appeared to rise and set would have their nights longer than their days; and the south pole would be constantly in darkness, with a tract around it equal to what was constantly in the light round the north pole. It is evident, also, that in this case the sun would be always on the north side of the equator, and vertical to a certain circle parallel to it, which would be as many degrees from the equator, as the angle contained between the earth's axis and the imaginary line wanted of a right angle.

This last supposition is in some degree similar to what actually takes place in nature; for the axis of the earth makes an angle of $23\frac{1}{2}$ degrees, with a perpendicular to its orbit; and as the axis always remains parallel to itself, or points in the same direction, this angle must be constantly changing as the earth moves forward in its orbit.*

This is well represented by the following figure, which shows the earth at twelve different times of the year.



The line *a b* is the equator, *n* the north pole, and *s* the south. The signs of ♐, ♒, &c. denote the points of the ecliptic in which the earth is when it has the positions in the figure.

As the position of the poles of the earth, with respect to the sun, depends entirely on this angle, their position must always be changing; and, of course, every point on the earth's surface must also alter its position with respect to the sun. About the 20th of March, when the sun, as seen from the earth, enters the sign Aries, the line supposed to join the centres of the earth and sun is perpendicular to the earth's axis; consequently both poles are

* Or, what amounts to the same thing, the axis of the earth makes an angle with the plane of the ecliptic of $66\frac{1}{2}$ degrees.

similarly situated with respect to the sun, as he is then directly over the equator, and the days and nights are equal at every place on the globe. This time of the year is called the *vernal* equinox, because spring commences to the inhabitants of the northern hemisphere, while autumn begins to those of the southern.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF GODEFROY WILLIAM DE LEIBNITZ.

Godefroy William de Leibnitz, an eminent mathematician and philosopher in the 17th century, was born at Leipsic in Saxony, in 1646. He soon made a prodigious progress in polite literature; and at the age of fifteen years he applied himself to mathematics at Leipsic and Jena; and upon his return to Leipsic in 1663, he maintained a thesis *de Principiis Individuationis*. The year following he was admitted master of arts. About this time he read with great attention the Greek philosophers; and endeavoured to reconcile Plato with Aristotle, as he afterwards did Aristotle with Des Cartes. But the study of the law was his principal view; in which faculty he was admitted bachelor in 1665. The year following he would have taken the degree of doctor, but was refused it on pretence that he was too young, but in reality because he had raised himself several enemies, by rejecting the principles of Aristotle and the schoolmen. Upon this he went to Altorf, where he maintained a thesis *de Casibus Perplexis* with such applause, that he had the degree of doctor conferred on him, and was offered a professorship extraordinary in law, which he refused. Thence he went to Nuremberg to visit the learned men there, and was introduced into the acquaintance of several persons engaged in the pursuit of the philosopher's stone. In 1672 he went to Paris, and there contracted a friendship with the learned men, and applied himself with vigour to the mathematics. Having observed some defects in the arithmetical machine of Mr. Pascal, he invented a new one, which was so approved by Mr. Colbert and the academy of sciences, that they offered him the place of pensionary-member. He might have settled to great advantage at Paris; but as it would have been necessary to have embraced the Roman Catholic religion, he refused all offers. In 1673 he went to England, where he became acquainted with Mr. Oldenburg, secretary of the Royal Society, and Mr. John Collins, fellow of that society. Soon after the elector of Mentz died, by which he lost his pension. He returned to France, whence he wrote a letter to the Duke of Brunswick, to inform him of his circumstances. The prince returned him a kind answer; and, as a pledge of his future favour, appointed him counsellor of his court, with a stipend, and gave him leave to continue at Paris till his arithmetical machine should be completed. In 1676 he returned to England, and thence went into Holland, in order to proceed to Hanover, where he proposed to settle. Upon his arrival there, he applied himself to enrich the duke's library with the best books of all kinds. The duke dying in 1679, his successor, Ernest Augustus, then bishop of Osnabrug, shewed our author the same favour as his predecessor had done, and ordered him to write the history of the house of Brunswick. He undertook it, and travelled over Germany and Italy in order to collect materials, and returned to Hanover in 1690. In 1700 he was admitted a member of the Royal Academy at Paris. The elector of Brandenburg, afterwards king of Prussia, founded an academy the same year at Berlin by his advice; and he was appointed perpetual president, though his affairs would not permit him to reside constantly at Berlin. However, he furnished their memoirs with several curious pieces in geometry, polite literature, natural philosophy, and even physic. He projected an academy of the same kind at Dresden, and communicated the plan to the king of Poland in 1703; and this design would have been executed, if it had not been prevented by the confusions in Poland. He was engaged likewise in a scheme for an universal language. His writings had long before made him famous over all Europe. Besides the office of privy-counsellor of justice, which the elector of Hanover had given him, the emperor appointed him in 1711 Aulic counsellor; and the czar made him his privy-counsellor of justice, with a pension of a thousand ducats, after a conversation with him at Torgaw, at the time of the marriage of the princess of Wolfenbuttel with the son of that prince. He undertook at the same time the establishment of an academy of the sciences at Vienna; but the plague prevented the execution of it. However, the emperor, as a mark of his favour, settled a pension on him of two thousand florins, and promised him another of four thousand, if he would come and reside at Vienna. He would have complied with this offer, but he was prevented by death. Upon his return to Hanover in 1714, he found that the elector, who was then raised to the throne of Great Britain, had appointed Mr. Eckhard his colleague in writing the history of Brunswick.—

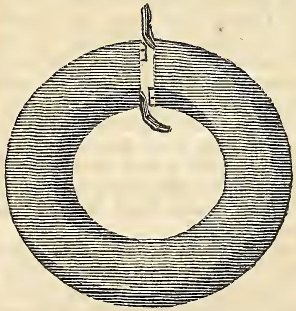
This work was interrupted by others which he wrote occasionally. The last affair he was engaged in was his dispute with Mr. Samuel Clarke; which was put an end to by Mr. Leibnitz's death, occasioned by the gout and stone, November 14th, 1716, aged 70. His memory was so strong, that, in order to fix any thing in it, he had no more to do but to write it once, and never read it again; and he could, even in his old age, repeat Virgil exactly. He was of a warm temper, and was very sensible of the honour of being considered as one of the greatest men in Europe. He made use of the favour of princes for learning as well as himself. He professed the Lutheran religion, but never went to sermon; and upon his death-bed, his coachman, who was his favourite servant, desiring him to send for a minister, he refused, saying, *he had no need of one*. Mr. Locke and Mr. Molyneux plainly seem to think he was not so great a man as he had the reputation of being; and, in truth, many of his metaphysical notions are quite unintelligible. In his *Theodicée* he seems to have had a confused idea of the true philosophy; but it is not well digested, nor did he seem to perceive all the consequences of it. However, he was certainly a great genius, but dissipated by too great ambition to excel in every thing. Foreigners did for some time ascribe to him the honour of an invention, of which he received the first hints from Sir Isaac Newton's letters, who had discovered the method of fluxions in 1664 and 1665. It would be tedious to give the reader a detail of the dispute concerning the right to that invention. The method of fluxions and the *Calculus Differentialis* are the same method of analysis under two different names. Sir Isaac Newton and the English call it the method of fluxions; but Leibnitz gave it the name of *Calculus Differentialis*, in which he has been followed by all the mathematicians abroad. The Marquis de l'Hospital published the elements of it under the title of *The Analysis of Infinitely Small Quantities*. The very learned and ingenious Dr. Berkely, bishop of Cloyn in Ireland, has given rise to many pamphlets in defence of this highly-boasted of science. Many ways of speaking, at least, in it were very exceptionable. But Mr. Maclauran, professor of the mathematics in the university of Edinburgh, published a treatise of fluxions; in which he proceeds with the preciseness of the ancient geometricians, has set the first principles of that science in a clear light, and carried it to a vast height of perfection. By so doing, he has put an end to verbal disputes, which had got into that science, as well as others, that had been long plagued and incumbered by them, and was like to have obstructed its progress, and employed men of genius in jangling more than invention. With regard to the disputes between him and Dr. Clarke about space, none of them express themselves clearly or philosophically enough. Nothing hath been reckoned by philosophers so obscure as time and place, or space; yet the vulgar, and they themselves, too, in the affairs of life, understand it very well. And yet I think every body would understand this proposition: a body would go on in the same line of direction for ever, did it meet with nothing to obstruct or retard its motion. Yet if this be understood, it is not difficult, one would imagine, to comprehend in what sense space may be said to be infinite, and wherein it differs from body or matter.

To the Editor of the Artisan.

Sir,

As it not unfrequently happens in cases of shipwreck, that various insurmountable obstacles prevent the possibility of either the people on shore or those in the stranded vessel, pursuing the whole of the plan given in your 22d No. p. 350, when the first part might be practised with success; permit me to point out two methods, either of which may at any time be resorted to, whenever a rope communication can by any means be attained between the shore and the wreck, and the single whip purchase is established.

A close net or canvas bag, invented by Mr. A. Bosquet in Feb. 1802, which I shall first describe, would be found a very useful accompaniment to the mortar apparatus, as it could be hauled to and fro by the whip in less time, perhaps, than any other machine of equal utility. This net, or canvas collar, should be made of dimensions, when stuffed with cork shavings, equal to about that of a small bed bolster, coiled or formed in this manner, like a



collar, and sufficiently wide for the head and shoulders to pass through, or be put on and off by straps and buckles, so that it may occupy the space between the arm-pits and the loins; this will sustain the person who has it on in an erect posture, and always high above the water, and most essentially protect him from those bruises on rocks which frequently prove fatal. It could be put on in a minute, and would not prevent the use of the limbs whenever ground was felt.

The following description of a wicker boat, which was also invented by Mr. Bosquet, and published at the same time with the above, is given in the *Naval Chronicle*, Vol. vii. p. 137; and as I am thoroughly convinced that most of the advantages mentioned by him would be gained by its use, I shall describe it in his own words:—" First, the figure may be either oval or round, the latter I would prefer; its form resembling a basin, composed of two frames of similar forms, constructed of wicker work, but of different diameters: the one laying within the other. The diameter of the inner frame at the mouth may be from five to six feet; the depth from the gunwale to the bottom, about three; the internal diameter at the bottom, which is to be flat, a third less than at the mouth; the space between the outer and inner frame, all round, and to its entire depth, may be about eighteen inches: this space to be closely filled with cork shavings, and closed with wicker work, or a light wooden gunwale. The bottom or area is to be furnished with two false lattice, or grated bottoms, of strong basket work, through which the water may have free egress and regress; the ground bottom may be on a plane with the lower extremes of the sides, which may be furnished with a wooden seat; and the inner or upper bottom placed at from nine to twelve inches higher within the boat, and sufficiently firm to bear the required pressure to which it must be subject; it therefore may be composed of a grated wooden frame. This boat, by its own weight, will not draw more than from five to six inches, and with the additional weight of eight men within, the water would not rise to the second bottom; and supposing that the boat might contain twenty men, which I think it might, yet the water would be found not to rise twelve inches internally above the second bottom. There should be a seat of wicker-work, all round stuffed like the sides, and about nine or ten inches high from the upper bottom.

" The advantages which would pertain to such a boat are—*First*, its cheapness and simplicity; it may cost about £5. *Secondly*, Any basket maker, with proper instructions, could make it. *Thirdly*, That of being conveniently portable; half a dozen men could carry it.—*Fourthly*, It would not upset.—*Fifthly*, The utmost number of persons that could force themselves into it, could not cause it to founder, or the water to rise internally more than twelve or fourteen inches. *Sixthly*, Though it might be filled for a moment, yet it would as suddenly free itself through its grated bottom.—*Seventhly*, Such a boat cannot go to pieces by any shock, nor can the most violent concussions against rocks, *or the sides of a ship*, do it any injury, as it will both yield and rebound by its elastic quality."

This last qualification mentioned by Mr. Bosquet, gives the wicker boat a decided superiority over every other, as it might without danger be hauled off through any sea without a man on board, which to another boat would be certain destruction. It might be hauled to and fro by the whip alone, or with both the whip and hawser, by reeving the hawser through two rollers fixed at opposite sides on her gunwale; this latter method would keep her more steady and better under command. Whenever the hawser is used, its in-shore end should be rove through the ring of a small anchor through which it can be veered, and hauled according to the motion of the wreck.

I am Sir,
Your obedient humble Servant,
NAVARCHUS.

January 21*st*, 1825.

SOLUTION OF QUESTIONS.

QUEST. 59, *answered by* J. ANDERSON, *(the Proposer.)*

Put 16 $\frac{1}{12}$ feet $= m$, $\cdot 7854 = n$, the area of each aperture, $a = 48$ inches, and $b = 60$ in. Then by hydrost. $\sqrt{m} : 2m :: \sqrt{a} : 2\sqrt{am} =$ the velocity of the water through the aperture at the bottom, and $2\sqrt{am - m}$ $=$ the velocity through the one in the side. $2n\sqrt{am} + 2n\sqrt{am - m} =$ the quantity discharged by both in the first second of time. Hence $\frac{b^2 \times \cdot 7854 \times a \times 2}{2\sqrt{am} + 2n\sqrt{am - m}} \times \frac{3}{2} =$ 24′ 9″ the time required.

QUESTION FOR SOLUTION.

QUEST. 62, *proposed by* J. D.

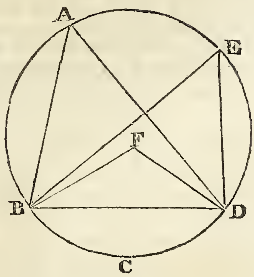
If 9 oxen eat up 3 acres of grass in 5 weeks, and 20 oxen eat up 10 acres of the same in 10 weeks; how many oxen will eat up 30 acres of the same in 25 weeks, if the grass grow uniformly during that time?

GEOMETRY.

PROPOSITION XXI.

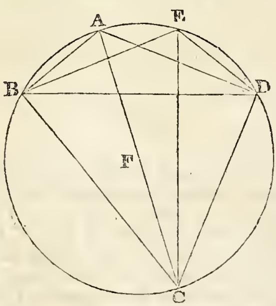
THEOREM.—*The angles in the same segment of a circle are equal to one another.*

Let A B C D be a circle, and B A D, B E D angles in the same segment BAED: The angles B A D, B E D are equal to one another.



Take F the centre of the circle A B C D: And, first, let the segment B A E D be greater than a semicircle, and join B F, F D: And because the angle B F D is at the centre, and the angle B A D at the circumference, and that they have the same part of the circumference; viz. BCD for their base; therefore the angle B F D is double of the angle B A D: For the same reason, the angle B F D is double of the angle B E D: Therefore the angle B A D is equal to the angle B E D.

But, if the segment B A E D be not greater than a semicircle, let BAD, B E D be angles in it; these also are equal to one another: Draw A F to the centre, and produce it to C, and join C E: Therefore the segment B A D C is greater than a semicircle; and the angles in it B A C, B E C are equal, by the first case: For the same reason, because C B E D is



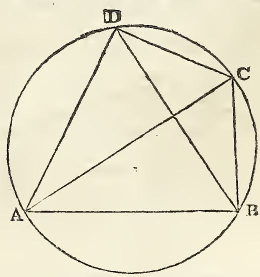
greater than a semicircle, the angles C A D, C E D are equal: Therefore the whole angle B A D is equal to the whole angle B E D. Wherefore the angles in the same segment, &c. Q. E. D.

PROPOSITION XXII.

THEOREM.—*The opposite angles of any quadrilateral figure described in a circle, are together equal to two right angles.*

Let A B C D be a quadrilateral figure in the circle A B C D; any two of its opposite angles are together equal to two right angles.

Join A C, B D; and because the three angles of every triangle are equal to two riget angles, the three angles of the triangle C A B; viz. the angles C A B, A B C, B C A, are equal to two right angles: But the angle C A B is equal to the angle C D B, because they are in the same segment B A D C, and the angle A C B is equal to the angle A D B, because they are in the same segment A D C B: Therefore the whole angle A D C is equal to the angles C A B, A C B: To each of these equals add the angle A B C; therefore the angles A B C, C A B,

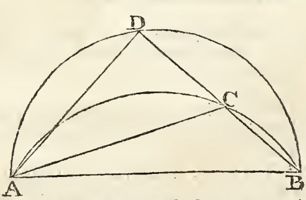


B C A, are equal to the angles A B C, A D C: But A B C, C A B, B C A, are equal to two right angles; therefore also the angles A B C, A D C are equal to two right angles: In the same manner the angles B A D, D A B, D C B, may be shown to be equal to two right angles. Therefore, the opposite angles, &c. Q. E. D.

PROPOSITION XXIII.

THEOREM.—*Upon the same straight line, and upon the same side of it, there cannot be two similar segments of circles, not coinciding with another.*

If it be possible, let the two similar segments of circles; viz. A C B, A D B, be



upon the same side of the same straight

E

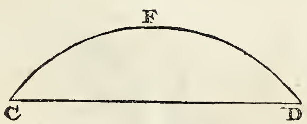
line A B, not coinciding with one another: then, because the circle A C B cuts the circle A D B in the two points A, B, they cannot cut one another in any other point: one of the segments must therefore fall within the other: let A C B fall within ADB, and draw the straight line BCD, and join C A, D A: and because the segment A C B is similar to the segment A D B, and that similar segments of circles contain equal angles, the angle A C B is equal to the angle A D B, the exterior to the interior opposite, which is impossible. Therefore, there cannot be two similar segments of circles upon the same side of the same line, which do not coincide. Q. E. D.

PROPOSITION XXIV.

Theorem.—*Similar segments of circles upon equal straight lines, are equal to one another.*

Let A E B, C F D be similar segments of circles upon the equal straight lines A B, C D; the segment A E B is equal to the segment C F D.

For, if the segment A E B be applied to



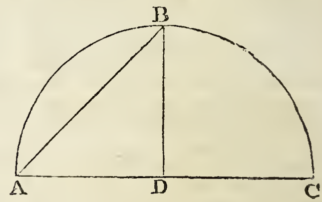
the segment C F D, so as the point A be on C, and the straight line A B upon C D, the point B shall coincide with the point D, because A B is equal to C D: Therefore the straight line A B coinciding with C D, the segment A E B must coincide with the segment C F D, and therefore is equal to it. Wherefore, similar segments, &c. Q. E. D.

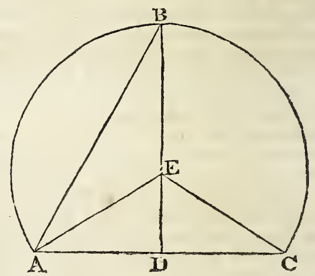
PROPOSITION XXV.

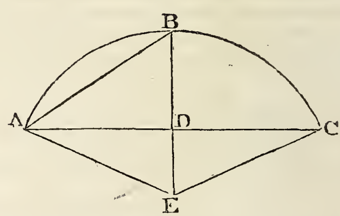
Problem.—*A segment of a circle being given, to describe the circle of which it is the segment.*

Let A B C be the given segment of a circle; it is required to describe the circle of which it is the segment.

Bisect A C in D, and from the point D draw D B at right angles to A C, and join A B: first, let the angles A B D, B A D be equal to one another; then the straight line B D is equal to D A, and therefore to D C; and because the three straight lines D A, D B, D C, are all equal; D is the centre of the circle: from the centre D, at the distance of any of the three D A, D B, D C, describe a circle; this shall pass through the other points; and the circle of which A B C is a segment is described: and because the centre D is in A C, the segment A B C is a semicircle. But if the angles A B D, B A D are not equal to one another, at the point A, in the straight line A B, make the angle B A E equal to the angle A B D, and produce B D, if necessary, to E, and join E C: and because the







angle A B E is equal to the angle B A E, the straight line B E is equal to E A: and because A D is equal to D C, and D E common to the triangles A D E, C D E, the two sides A D, D E are equal to the two C D, D E, each to each; and the angle A D E is equal to the angle C D E, for each of them is a right angle; therefore the base A E is equal to the base E C: but A E was shown to be equal to E B, wherefore also B E is equal to E C:

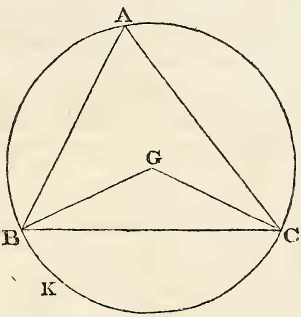
and the three straight lines A E, E B, E C are therefore equal to one another; wherefore E is the centre of the circle. From the centre E, at the distance of any of the three A E, E B, E C, describe a circle, this shall pass through the other points; and the circle of which A B C is a segment is described: also it is evident, that if the angle A B D be greater than the angle B A D, the centre E falls without the segment A B C, which therefore is less than a semicircle: but if the angle A B D be less than B A D, the centre E falls within the segment A B C, which is therefore greater than a semicircle: Wherefore, a segment of a circle being given, the circle is described of which it is a segment. Which was to be done.

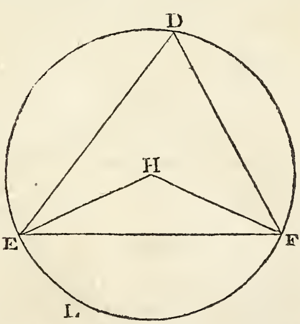
PROPOSITION XXVI.

THEOREM.—*In equal circles, equal angles stand upon equal arches, whether they be at the centres or circumferences.*

Let A B C, D E F be equal circles, and the equal angles B G C, E H F at their centers, and B A C, E D F, at their circumferences: the arch B K C is equal to the arch E L F.

Join B C, E F; and because the circles A B C, D E F are equal, the straight lines drawn from their centres are equal: there-





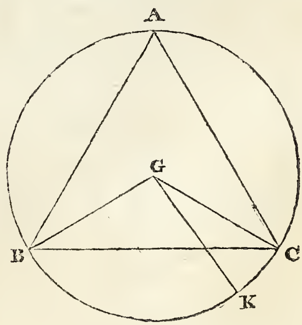
fore the two sides B G, G C are equal to the two E H, H F; and the angle at G is equal to the angle at H; therefore the base B C is equal to the base E F: and because the angle at A is equal to the angle at D, the segment B A C is similar to the segment E D F; and they are upon equal straight lines B C, E F; but similar segments of circles upon equal straight lines are equal to one another, therefore the segment B A C is equal to the segment E D F: but the whole circle A B C is equal to the whole D E F; therefore the remaining segment B K C is equal to the remaining segment E L F, and the arch B K C to the arch E L F. Wherefore in equal circles, &c. Q. E. D.

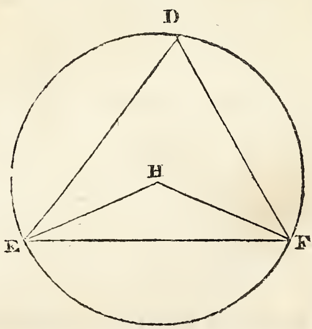
PROPOSITION XXVII.

THEOREM.—*In equal circles, the angles which stand upon equal arches are equal to one another, whether they be at the centres or circumferences.*

Let the angles B G C, E H F at the centres, and B A C, E D F at the circumferences of the equal circles A B C, D E F stand upon the equal arches B C, E F: the angle B G C is equal to the angle E H F, and the angle B A C to the angle E D F.

If the angle B G C be equal to the angle E H F, it is manifest that the angle B A C is also equal to E D F. But, if not, one of them is the greater: let B G C be the





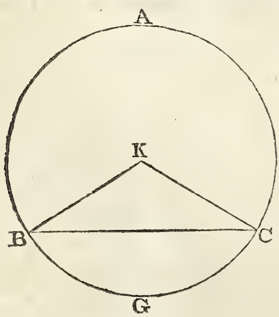
greater, and at the point G, in the straight line B G, make the angle B G K equal to the angle E H F. And because equal angles stand upon equal arches, when they are at the centre, the arch B K is equal to the arch E F: but E F is equal to B C; therefore also B K is equal to B C, the less to the greater, which is impossible. Therefore the angle B G C is not unequal to the angle E H F; that is, it is equal to it: and the angle at A is half of the angle B G C, and the angle at D half of the angle E H F: therefore the angle at A is equal to the angle at D. Wherefore, in equal circles, &c. Q. E. D.

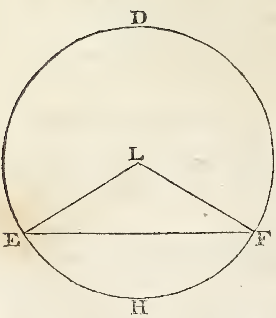
PROPOSITION XXVIII.

Theorem.—*In equal circles, equal straight lines cut off equal arches, the greater equal to the greater, and the less to the less.*

Let A B C, D E F be equal circles, and B C, E F equal straight lines in them, which cut off the two greater arches B A C, E D F, and the two less B G C, E H F: the greater B A C is equal to the greater E D F, and the less B G C to the less E H F.

Take K, L, the centres of the circles, and join B K, K C, E L, L F: and because





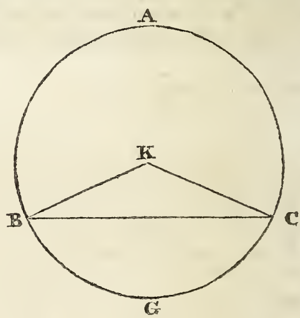
the circles are equal, the straight lines from their centres are equal; therefore B K, K C are equal to E L, L F; but the base B C is also equal to the base E F; therefore the angle B K C is equal to the angle E L F: and equal angles stand upon equal arches, when they are at the centres; therefore the arch B G C is equal to the arch E H F. But the whole circle A B C is equal to the whole E D F; the remaining part, therefore, of the circumference; viz. B A C, is equal to the remaining part E D F. Therefore, in equal circles, &c. Q. E. D.

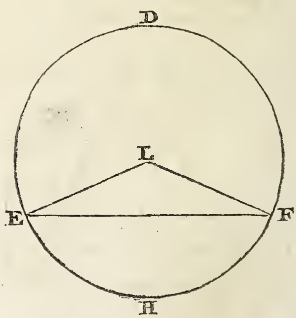
PROPOSITION XXIX.

Theorem.—*In equal circles equal arches are subtended by equal straight lines.*

Let A B C, D E F be equal circles, and let the arches B G C, E H F also be equal, and join B C, E F: the straight line B C is equal to the straight line E F.

Take K, L, the centres of the circles, join B K, K C, E L, L F: and because the arch B G C is equal to the arch E H F, the angle B K C is equal to the angle E L F: also because the circles A B C, D E F are equal, their radii are equal: therefore B K, K C are equal to E L,





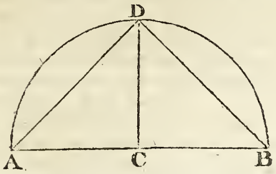
L F, and they contain equal angles: therefore the base B C is equal to the base E F. Therefore, in equal circles, &c. Q. E. D.

PROPOSITION XXX.

PROBLEM.—*To bisect a given arch; that is, to divide it into two equal parts.*

Let A D B be the given arch; it is required to bisect it.

Join A B, and bisect it in C; from the point C draw C D at right angles to A B,



and join A D, D B: the arch A D B is bisected in the point D.

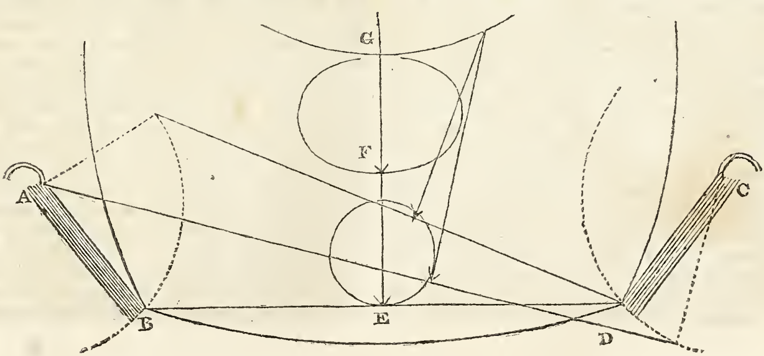
Because A C is equal to C B, and C D common to the triangles A C D, B C D, the two sides A C, C D are equal to the two B C, C D; and the angle A C D is equal to the angle B C D, because each of them is a right angle; therefore the base A D is equal to the base B D. But equal straight lines cut off equal arches, the greater equal to the greater, and the less to the less; and A D, D B are each of them less than a semicircle, because D C passes through the centre: Wherefore the arch A D is equal to the arch D B; and therefore the given arch A D B is bisected in D. Which was to be done.

MECHANICS.

ON WHEEL CARRIAGES.

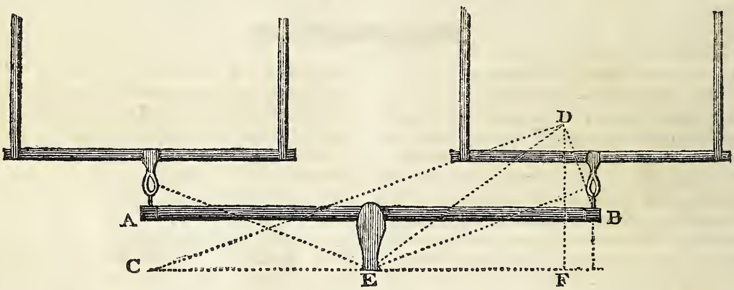
The effect of the suspension of a carriage on springs, is to equalize its motion, by causing every change to be more gradually communicating to it, by means of the flexibility of the springs, and by consuming a certain portion of every sudden impulse, in generating a degree of rotatory motion. This rotatory motion depends on the oblique position of the straps suspending the carriage, which prevents its swinging in a parallel direction; such a vibration as would take place, if the straps were parallel, would be too extensive, unless they were very short, and then the motion would be somewhat rougher. The obliquity of the straps tends also in some measure to retain the carriage in a horizontal position: for if they were parallel, both being vertical, the lower one would have to support the greater portion of the weight, at least according to the common mode of fixing them to the bottom of the carriage; the spring, therefore, being flexible, it would be still further depressed. But when the straps are oblique, the upper one assumes always the more vertical position, and consequently bears more of the load; for when a body of any kind is supported by two oblique forces, their horizontal thrusts must be equal, otherwise the body would move more laterally; and in order that the horizontal portions of the forces may be equal, the more inclined to the horizon must be the greater: the upper string will, therefore, be a little depressed, and the carriage will remain more nearly horizontal than if the springs were parallel. The reason for dividing the springs into separate plates, has already been explained: the beam of the carriage that unites the wheels, supplies the strength necessary for forming the communication between the axles; if the body of the carriage itself was to perform this office, the springs would require to be so strong, that they could have little or no effect in equalizing the motion, and we should have a waggon instead of a coach. The ease with which a carriage moves, depends not only on the elasticity of the springs, but also on the small degree of stability of the equilibrium, of which we may judge in some measure, by tracing the path which the centre of gravity must describe, when the carriage swings.

In the following figure A B and C D represent the straps or braces by which a



coach is suspended, if the centre of gravity be at E, F, or G, it must move, when the carriage swings in the curve passing through the respective point.

The modes of attaching horses and oxen to carriages are different in different countries, nor is it easy to determine the most eligible method. When horses are harnessed to draw side by side, they are usually attached to the opposite ends of a bar or lever; and if their strength is very unequal, the bar is sometimes unequally divided by the fulcrum, the weaker horse being made to act on the longer bar, and being thus enabled to counteract the greater force of his companion. But even without this inequality, a compensation takes place, for the centre on which the bar moves, is always considerably behind the points of attachment of the horses; and when one of them falls back a little, the effective arm of the lever becomes more perpendicular to the direction of his force, and gives him a greater power, while the opposite arm becomes more oblique, and causes the other horse to act at a disadvantage, so that there is a kind of stability in the equilibrium. If the fulcrum were farther forwards than the extremity of the bar, the two horses could never draw together with convenience. The following figure represents the mode of harnessing two horses, so as to make them draw conveniently together:



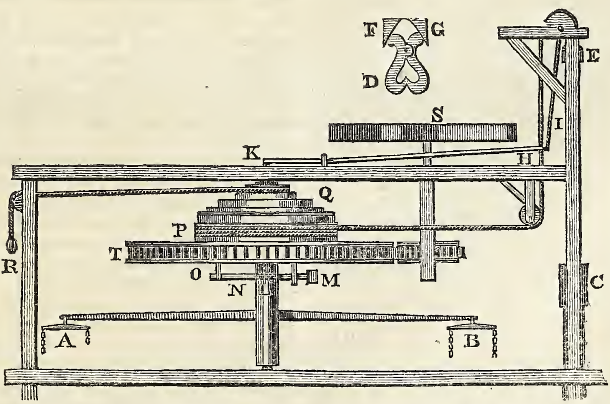
When either horse advances so far that the bar A B assumes the position C D, the foremost horse has the disadvantage of acting on a lever, equivalent only to E F, while the other horse acts on E C.

In mining countries, and in collieries, it is usual for facilitating the motion of the carriages, employed in moving the ore or the coals, to lay wheel-ways of wood or iron along the road on which they are to pass; and this practice has of late been extended in some cases, as a substitute for the construction of navigable canals. Where there is a turning, the carriages are usually received on a frame supported by a pivot, which allows them to be turned with great ease. In particular situations these waggons are loaded by little carts, rolling without direction down inclined planes, and emptying themselves; they are also provided with similar contrivances for being readily unloaded, when they arrive at the place of their destination. The carriages used for drawing loaded boats over inclined planes, where they have to ascend and again to descend, are made to preserve their level, by having at one end four wheels instead of two, on the same transverse line; the outer one as much higher than the pair at the other end, as the inner ones are lower: and the wheel-way being so laid, that either the largest or the smallest act on it; according as the corresponding part of the plane is lower or higher than the opposite end.

It is probable that roads paved with iron, or what is termed rail-roads, may hereafter be employed for the purpose of expeditious travelling, since there is scarcely any resistance to be overcome, except that of the air; consequently such roads would allow the velocity to be increased almost without limit. On this interesting subject we have just learned the result of a grand experiment, performed at Killingworth Colliery, near Newcastle-upon-Tyne, in presence of several gentlemen from the committees appointed to manage the intended Manchester and Liverpool, and the Birmingham and Liverpool rail-roads about to be made. The experiment was made with a *locomotive steam engine* of eight horse power, and weighing, with the tender (containing water and coals), five tons and ten hundred weight, was placed on a portion of rail-rood, the inclination of which, in one mile and a quarter, was stated by the proprietor Mr. Wood, to be one inch in a chain, or one part in 792: twelve waggons were placed on the rail-road, each containing two tons and between 13 and 14 hundred weight of coals—making a total useful weight of 32 tons and 8 cwt. The twelve waggons were drawn one mile and a quarter each way, making two miles and a half in the whole, in forty minutes, or at the rate of $3\frac{1}{4}$ miles an hour, consuming four pecks and a half of coals. Eight waggons were then drawn the same distance in thirty-six minutes, consuming four pecks of coals; and six waggons were drawn over the same ground in thirty-two minutes, consuming five pecks of coals. We understand that the engine must be supplied with hot or boiling, and not with cold water; and that two hundred gallons of water will take the engine 14 miles, at the end of which the supply must be renewed.

ENGINE FOR DRIVING PILES.

In the engine for driving piles or upright beams, used for the foundations of buildings in water, or in soft ground, the weight is raised slowly to a considerable height, in order that, in falling, it may acquire sufficient energy to propel the pile with efficacy. The same force, if applied by very powerful machinery immediately to the pile, would perhaps produce an equal effect in driving it; but it would be absolutely impossible in practice to construct machinery strong enough for the purpose, and if it were possible, there would be an immense loss of force from the friction. For example: supposing a weight of 500 pounds, falling from a height of 50 feet, to drive the pile 2 inches at each stroke; then, if the resistance be considered as nearly uniform, its magnitude must be about 150 thousand pounds, and the same moving power, with a mechanical advantage of 300 to 1, would perform the work in the same time. But for this purpose, some parts of the machinery must be able to support a strain equivalent to the draught of 600 horses. In the pile-driving engine, the forceps or tongs, sometimes called the monkey or follower, is opened as soon as the weight arrives at its greatest height; and at the same time a lever detaches the drum employed for raising the weight, from the axis or windlass at which the horses are drawing; the follower then descends after the weight, uncoiling the rope from the drum, and the force of the horses is employed in turning a fly-wheel, until the connection with the weight is again restored. The following figure represents an engine of this kind on Vauloue's construction.



The horses drawing at A B, raise the weight C, held by the tongs D, fixed in the follower E, which are opened when they reach the summit, by being pressed between the inclined planes F G, so as to let the weight fall. At the same time the lever H is raised by the rope I, and presses on the pin K L, so as to depress the lever M N, and draw the pin out of the drum P Q; the follower then descends and uncoils the rope, its too rapid motion being prevented by the counterpoise R, acting on the spiral barrel Q. The motion is regulated by the fly S, the pinion of which is turned by the great wheel T.

Having described the construction and operation of the pile engine, we shall here make a few remarks on the manner of regulating forces.

If a machine were constructed for raising a solid weight, and so arranged, as to perform its office in the shortest possible time with a given expense of power, the weight would still possess, when it arrived at the place of its destination, a considerable and still increasing velocity: in order that it might retain its situation, it would be necessary that this velocity should be destroyed; if it were suddenly destroyed, the machinery would undergo a strain which might be very injurious to it: and if the velocity were gradually diminished, the time would no longer be the same. In the second place; the forces generally employed are by no means uniformly accelerating forces, like that of gravitation: they are not only less active when a certain velocity has once been attained, but they are often capable of a temporary increase or diminution of intensity at pleasure. We have mentioned the inconvenience of producing a great final velocity, on account of its endangering the structure of the machine; if, therefore our permanent force be calculated according to the common rule, so as to be able to maintain the equilibrium, and overcome the friction, the momentum or inertia of the weights, when once set in motion, will be able to sustain that motion equably; and it will not be difficult to give them a sufficient momentum, by a greater exertion of the moving force, for a short space of time, at the beginning: and this is in fact the true mode of operation of many machines where animal strength is employed. Other forces, for instance those of wind and water, regulate themselves in some measure, at least with respect to the relative velocity of the sails and the wind, or the floatboards and the water; for we may easily increase the resistance, until the most advantageous effect is produced. If we compare the greatest velocity with which a man or a horse can run or walk without fatigue, to the velocity of a stream of water, and the actual velocity of that part of the machine to which the force is applied, to the velocity of the float-boards of a water wheel, the strength which can be exerted may be represented, according to the experiments of some authors, by the impulse of the stream, as supposed to be proportional to the square of the relative velocity; consequently the same velocity would be most advantageous in both cases, and the man or horse ought, according to these experiments, to move, when his force is applied to a machine, with one third of the velocity with which he could walk or run when at liberty. This, for a man, would be about a mile and a half an hour; for a horse, two or three miles: but in general both men and horses appear to work most advantageously with a velocity somewhat greater than this.*

Where a uniformly accelerating force, like that of gravitation, is employed in machines, it might often be of advantage to regulate its operation, so that it might act nearly in the same manner as the forces that we have been considering; at first with greater intensity, and afterwards with sufficient power to sustain the equilibrium, and overcome the friction only. This might be done, by means of a spiral barrel, like the fusee of a watch; and a similar modification has sometimes been applied, by causing the ascending weight, when it arrives near the place of its destination, to act on a counterpoise, which resists it with a force continually increasing, by the operation of a barrel of the same kind, so as to prevent the effect of the shock which too rapid a motion would occasion.

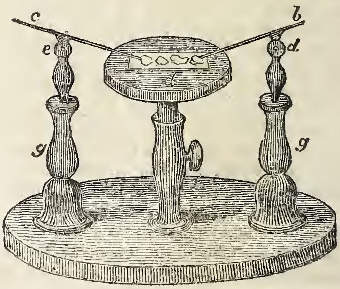
On the whole, we may conclude, that on account of the limited velocity which is usually admissible in the operation of machines, a very small portion of the moving force is expended in producing momentum; the velocity of 3 miles an hour, would be generated in a heavy body, descending by its own weight, in one seventh of a second, and a very short time is generally sufficient for obtaining as rapid a motion as the machine or the nature of the force will allow; and when this has been effected, the whole force is employed in maintaining the equilibrium, and overcoming the resistance.

* See page 276, vol. i.

ELECTRICITY.

The production of heat by electricity frequently accompanies that of light, and appears to depend in some measure on the same circumstances. A fine wire may be fused and dissipated by the discharge of a battery; and without being perfectly melted, it may sometimes be shortened or lengthened, accordingly as it is loose or stretched during the experiment. The more readily a metal conducts, the shorter is the portion of it which the same shock can destroy; and it has sometimes been found, that a double charge of a battery has been capable of melting a quadruple length of wire of the same kind.

The powerful effect of a battery may be very readily illustrated by the following experiment. Let two or three pieces of gold leaf be put at the distance of $\frac{1}{10}$th of an inch from each other, between two thin slips of window-glass, on the ivory table *a* in the following figure,



and be held fast to the table by the rods *c* and *b*, turning on the stiff joints *e* and *d*, and insulated by the glass legs *g g*. If the battery, (page 41,) be charged, and a wire or chain from the hook *e* join the rod *c*, and the knob *z* of the discharging rod touch the rod *b*, at the same time that its other knob *a* touches the knob *c* of the battery, the discharge will pass between the glass slips, break them in its passage, melt or rather oxydize the gold leaf, and enamel or incorporate it with the pieces of broken glass. If a small weight be placed on the glass slips, the experiment will succeed still better.

The mechanical effects of electricity are probably in many cases the consequences of the rarefaction produced by the heat which is excited; thus, the explosion, attending the transmission of a shock or spark through the air, may easily be supposed to be derived from the expansion caused by heat; and the destruction of a glass tube, which contains a fluid in a capillary bore, when a spark is caused to pass through it, is the natural consequence of the conversion of some particles of the fluid into vapour. But when a glass jar is perforated, this rarefaction cannot be supposed to be adequate to the effect. It is remarkable that such a perforation may be made by a very moderate discharge, when the glass is in contact with oil or with sealing wax; and no sufficient explanation of this circumstance has yet been given.

A strong current of electricity, or a succession of shocks or sparks, transmitted through a substance, by means of fine wires, is capable of producing many chemical combinations and decompositions, some of which may be attributed merely to the heat which it occasions, but others are wholly different. Of these the most remarkable is the production of oxygen and hydrogen gas from common water, which are usually extricated at once, in such quantities, as, when again combined, will reproduce the water which has disappeared; but in some cases the oxygen appears to be disengaged most copiously at the positive wire, and the hydrogen at the negative.

When the spark is received by the tongue, it has generally a subacid taste; and an explosion of any kind is usually accompanied by a smell somewhat like that of sulphur, or rather of fired gunpowder. The peculiar sensation, which the electric fluid occasions in the human frame, appears in general to be derived from the spasmodic contractions of the muscles through which it passes; although in some cases it produces pain of a different kind; thus, the spark of a conductor occasions a disagreeable sensation in the skin, and when an excoriated surface is placed in the galvanic current, a sense of smarting, mixed with burning, is experienced. Sometimes the effect of a shock is felt most powerfully at the joints, on account of the difficulty which the fluid finds in passing the articulating surfaces which form the cavity of the joints. The sudden death of an animal, in consequence of a violent shock, is probably owing to the immediate exhaustion of the whole energy of the nervous system. It is remarkable that a very minute tremor, communicated to the most elastic parts of the body, in particular to the chest, produces an agitation of the nerves, which is not wholly unlike the effect of a weak electricity.

The electricity produced by the simple contact of any two substances is extremely weak, and can only be detected by very delicate experiments: in general it appears that the substance, which conducts the more readily, acquires a slight degree of negative electricity, while the other substance is positively electrified in an equal degree. The same disposition of the fluid is also usually produced by friction, the one substance always losing as much as the other gains; and commonly, although not always, the worst conductor becomes positive. At the instant in which the friction is applied, the capacities or attractions of the bodies for electricity appear to be altered, and a greater or less quantity is required for saturating them; and upon the cessation of the temporary change, this redundancy or deficiency is rendered sensible. When two substances of the same kind are rubbed together, the smaller or the rougher becomes negatively electrified; perhaps because the smaller surface is more heated, in consequence of its undergoing more friction than an equal portion of the larger, and hence becomes a better conductor; and because the rougher is in itself a better conductor than the smoother, and may possibly have its conducting powers increased by the greater agitation of its parts which the friction produces. The back of a live cat becomes positively electrified, with whatever substance it is rubbed; glass is positive in most cases, but not when rubbed with mercury in a vacuum, although sealing wax, which is generally negative, is rendered positive by immersion in a trough of mercury. When a white and a black silk stocking are rubbed together, the white stocking acquires positive electricity, and the black negative, perhaps because the black dye renders the silk both rougher and a better conductor.

Vapours are generally in a negative state; but if they rise from metallic substances, or even from some kinds of heated glass, the effect is uncertain, probably on account of some chemical actions which interfere with it. Sulphur becomes electrical in cooling, and wax candles are said to be sometimes found in a state so electrical, when they are taken out of their moulds, as to attract the particles of dust which are floating near them. The tourmalin, and several other crystallized stones, become electrical when heated or cooled, and it is found that the disposition, assumed by the fluid, bears a certain relation to the direction in which the stone transmits the light most readily; some parts of the crystal being rendered always positively and others negatively electrical, by an increase of temperature.

If a piece of window-glass be laid on a warm poker, and the tourmalin on the glass, the glass will become negative, and the side of the stone touching it will be positive. The heat excites the tourmalin, and qualifies it to absorb electricity from the glass; the glass of course becomes negative, while the fossil is in a state of condensation.

Electricity does not appear over the whole surface of the stone, but only on two opposite sides, like the poles of a loadstone; so that its virtue lies in the direction of its strata, and, therefore, is capable of being forced, or drawn, to or from one pole towards the other, by heating, cooling, or friction. When put in the fire, it becomes covered with ashes; when rubbed with silk it emits strong flashes; and is luminous when warmed in the dark: so that changing the degree of heat, is what excites the stone.

That the animal nerve is a vehicle for electricity, and perhaps the cause of sensation, many experiments make more than probable. In the torpedo, we find an electrical battery, abstracted from the vessels appropriated to the animal functions; it consists of a great number of vessels like an honey-comb, standing across the fish, from its belly to its back; so that if one hand touches the belly, and the other the back, an electric shock is instantly felt, and the fish is convulsed. If the fish be touched with a stick, a numbness seizes the hand that holds the stick. The same effect takes place, if a charged battery be touched with a stick, because the stick is a bad conductor, and the electric matter can only pass through it in a stream, benumbing the hand in its passage; but a regular conducting power from its positive and negative sides, would be a shock. The electric eel, or gymnotus, has a stronger electrical power than the torpedo: the head and shoulders of this fish contain the animal functions; the rest seems all electrical: and electrical by volition, for the creature has the power of exerting or withholding the shock. If one hand be put in the water, and the other touch the eel, a violent shock takes place. Mr. Walker says he electrified thirty people at once with this eel; and that sparks have been produced by an electric circuit of this kind. How these two species of fish collect and retain their electricity, in a conducting medium, is an inexplicable wonder; they were no doubt endowed with this power for defence, and catching their prey; and have organs to secrete it from the water as other animals secrete nutrition from the heterogeneous contents of the stomach.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF SIR CHRISTOPHER WREN.

Sir Christopher Wren was one of the greatest philosophers and mathematicians, as well as one of the most learned and eminent architects, of his age. He was the son of the Rev. Christopher Wren, Dean of Windsor, and was born at Knoyle, in Wiltshire, in 1632. He studied at Wadham College, Oxford, where he took the degree of Master of Arts in 1653, and was chosen Fellow of All Souls' College there. Soon after he became one of that ingenious and learned society, who then met at Oxford, for the improvement of natural and experimental philosophy, and which at length produced the Royal Society.

When very young, he discovered a surprising genius for the mathematics; in which science he made great advances before he was sixteen years of age. In 1657 he was made Professor of Astronomy in Gresham College, London; and his lectures, which were much frequented, tended greatly to the promotion of real knowledge. He proposed several methods by which to account for the shadows returning backward ten degrees on the dial of King Ahaz, by the laws of nature. One subject of his lectures was upon telescopes, to the improvement of which he had greatly contributed; another was on certain properties of the air, and the barometer. In the year 1658 he read a description of the body and different phases of the planet Saturn; which subject he proposed to investigate, while his colleague, Mr. Rooke, then professor of geometry, was carrying on his observations upon the satellites of Jupiter. The same year he communicated some demonstrations concerning cycloids to Dr. Wallis, which were afterwards published by the Doctor at the end of his treatise upon that subject. About that time also he resolved the problem proposed by Pascal, under the feigned name of John de Montford, to all the English mathematicians; and returned another to the mathematicians in France, formerly proposed by Kepler, and then resolved likewise by himself, to which they never gave any solution. In 1660 he invented a method for the construction of solar eclipses; and in the latter part of the same year he, with ten other gentlemen, formed themselves into a society, to meet weekly, for the improvement of natural and experimental philosophy; being the foundation of the Royal Society. In the beginning of 1661 he was chosen Savilian Professor of Astronomy at Oxford, in the room of Dr. Seth Ward; where he was the same year created Doctor of Laws.

Among his other accomplishments, Dr. Wren had gained so considerable a skill in architecture, that he was sent for the same year from Oxford, by order of King Charles the Second, to assist Sir John Denham, surveyor-general of the works. In 1663 he was chosen Fellow of the Royal Society, being one of those who were first appointed by the council after the grant of their charter. Not long after, it being expected that the King would make the society a visit, the Lord Brounker, then president, by a letter, requested the advice of Dr. Wren, concerning the experiments which might be most proper on that occasion. To whom the Doctor recommended principally the Torricellian experiment, and the weather needle, as being not mere amusements, but useful, and also neat in their operation.

In 1665 he travelled into France, to examine the most beautiful edifices and curious mechanical works there, when he made many useful observations. Upon his return home, he was appointed architect, and one of the commissioners for repairing St. Paul's cathedral. Within a few days after the fire of London, 1666, he drew a plan for a new city, and presented it to the king; but it was not approved by the parliament. In this model the chief streets were to cross each other at right angles, with lesser streets between them; the churches, public buildings, &c. so disposed, as not to interfere with the streets, and four piazzas placed at proper distances. Upon the death of Sir John Denham, in 1668, he succeeded him in the office of surveyor-general of the king's works; and from this time he had the direction of a great many public edifices, by which he acquired the highest reputation. He build the magnificent theatre at Oxford, St. Paul's Cathedral, the Monument, the modern partof Hampton Court, Chelsea College, one of the wings of Greenwich Hospital, the churches of St. Stephen Walbrook and St. Mary-le-Bow, with upwards of sixty other churches and public works, which that dreadful fire made necessary. In the management of which business he was assisted in the measurements, and laying out of private property, by the ingenious Dr. Robert Hook. The variety of business in which he was by this means engaged, requiring his constant attendance and concern, he resigned his Savilian Professorship at Oxford in 1673; and the year following he received from the king the honour of knighthood. He was one of the commissioners who, on the motion of Sir Jonas Moore, surveyor-general of the ordnance, had been appointed to find out a proper place for erecting an observatory; and he proposed Greenwich, which was approved of; the foundation stone of which was laid the 10th of August, 1675, and the building was afterwards finished, under the direction of Sir Jonas, with the advice and assistance of Sir Christopher.

In 1680 he was chosen President of the Royal Society; afterwards appointed architect and commissioner of Chelsea College; and in 1684, principal officer or comptroller of the works in Windsor Castle. Sir Christopher sat twice in Parliament, as a representative for two different boroughs. While he continued surveyor-general, his residence was in Scotland-yard; but after his removal from that office, in 1718, he lived in St. James's-street, Westminster. He died the 25th of February, 1723, at 91 years of age; and he was interred with great solemnity in St. Paul's Cathedral, in the vault under the south wing of the choir, near the east end.

OF ELECTRICITY DEVELOPED DURING CHEMICAL ACTION.

Mr. Becquerel, of the Royal Academy of Sciences in France, has just published some important remarks upon the above subject. In the first place, he has demonstrated that the electricity developed in chemical action was not appreciable by the apparatus at present in use. In order to prove this, the following experiment was made:—Since, in the action of an acid upon a metal, the acid takes the positive, and the metal the negative electricity, an attempt was made to form a battery with couples, each composed of a metal and an acid; a slip of copper was then bent, and one of its extremities plunged into an acid, and the other in a concentrated solution of a hydrate of potash. Supposing an electric tension, the acid would keep the positive electricity, and transmit the negative electricity to the alkaline solution. A dozen of these plates were afterwards united by means of curved platina wires; one of the ends of each being plunged into the acid, and the other into the neighbouring alkaline solution. This disposition was really that which was proper for an electric battery, and the distribution of the electricity ought to take place in it conformably to the theory of Volta, in the case in which each couple would have had an electric tension, however slight.

This kind of battery being in action, the two ends of the galvanometrical wire were plunged into the two extreme liquids, where the tension was expected to be the strongest; and it was immediately perceived that the variation of the magnetic needle was less than that which would have been obtained with a single couple. It was then demonstrated, that the electricity developed during chemical action had no sensible tension; and hence it is sufficiently clear why Sir H. Davy could not obtain electricity with a condensator, during the action of the sulphuric acid upon the potash.

Mr. Becquerel has likewise directed his attention to the measure of chemical action, by means of electro-chemical effects. The experiment which led him to this was as follows:—In plunging unequally the two ends of a metallic wire into an acid capable of attacking it, he observed a current of electricity pass from the end the most attacked to the other. He began by analysing this phenomenon, and afterwards discovered an apparatus, by the assistance of which, chemical action may be measured. This apparatus is composed of two platina vases reposing upon a wire of the same metal. If the object is to ascertain which of the substances acts the most strongly upon an acid, two platina wires are to be taken, and the ends fixed in two cups filled with mercury, themselves communicating with the extremities of the galvanometrical wire; afterwards, by means of hooks, likewise of platina, two small fragments of different substances, neither of which exercises any electromotive action upon the metal, are attached to the extremity of these wires; these substances are made to touch the acid at the same time, so that the number of points of contact may be nearly the same; the electric current that will then manifest itself will pass from that substance which has experienced the stronger action on the part of the acid to the other.

When the chemical actions of metals upon an acid are to be compared, small wires of these metals are substituted for those of platina; and, instead of the mercury, the cups are filled with an alkaline solution. By operating in this manner, it has already been discovered that nitric acid acts more powerfully upon potash than upon soda; that soda was more attacked than zinc, &c.

If the relation between the chemical actions of two acids upon one base is sought, these acids are put into the two small platina vases above-mentioned, into which two fragments of the same substance, each suspended to one end of the platina wire, must be plunged at the same time, and equally. The direction of the current in this instance also will determine which of the acids has acted with the greater energy.

The question, however, whether the energy with which an acid attacks a base can serve to measure their reciprocal affinity, cannot yet be satisfactorily resolved; but there is reason to think that a relation must exist between these two effects, since the greater the affinity of one body for another, the more rapidly these bodies must approximate when in combination. It may, therefore, be reasonably supposed, that the relations between chemical actions, found as above, do not differ greatly from those which would result from a comparison of their affinities.

ON PREDICTING THE WEATHER.

From a very great number of meteorological observations, made in England between the years 1677 and 1789, Mr. Kirwan has deduced the following probable conjectures of the weather:—

1. That when there has been no storm before or after the vernal equinox, the ensuing summer is generally *dry*, at least five times in six.

2. That when a storm happens from any easterly point, either on the 19th, 20th, or 21st of March, the succeeding summer is generally *dry*, four times in five.

3. That when a storm arises on the 25th, 26th, or 27th of March, and not before, in any point, the succeeding summer is generally *dry*, four times in five.

4. If there be a storm at S. W., or W. S. W., on the 19th, 20th, 21st, or 22d of March, the succeeding summer is generally *wet*, four times in five.

To the above we shall add the following observations from the Encyclopedia Britannica.

1. A moist autumn, with a mild winter, is generally followed by a cold and dry spring, which greatly retards vegetation.

2. If the summer be remarkably rainy,

it is probable that the ensuing winter will be severe; for the unusual evaporation will have carried off the heat of the earth. Wet summers are generally attended with an unusual quantity of seed on the white thorn and dog-rose bushes. Hence the unusual fruitfulness of these shrubs is a sign of a severe winter.

3. The appearance of cranes, and birds of passage, early in autumn, announces a very severe winter; for it is a sign that it has already begun in the northern countries.

4. When it rains plentifully in May, it will rain but little in September, and vice versa.

5. When the wind is S.W. during summer or autumn, and the temperature of the air unusually cold for the season, both to the feeling and the thermometer, with a low barometer, much rain is to be expected.

6. Violent temperatures, as storms or great rains, produce a sort of crisis in the atmosphere, which produces a constant temperature, good or bad, for some months.

7. A rainy winter predicts a sterile year; a severe autumn announces a windy winter.

By the Barometer.

It is now a considerable time since the barometer was proposed as a proper instrument for predicting the weather; and hence it obtained the name of *weather glass.* Accordingly, rules for this purpose have been given by Dr. Halley, Dr. Hutton, Messrs. Pascal, Patrick, Rowning, Changeux, de Luc, Clarke, Dalton, and many others, from whose writings we have collected the following rules.

When the mercury in the barometer rises, it is a sign of fair weather, attended with heat, if in summer; but frost in winter. If the mercury falls, it denotes rain, or wind, or perhaps both.

If the mercury rises suddenly during the time of rain, the ensuing fair weather will not continue long; but if the rise is gradual, and continues for several days, a continuance of fair weather may be expected.

If the mercury falls suddenly several divisions, it is a sign that the succeeding rain will not be of long duration. But if the mercury continues to fall regularly for several days, rain or wind, or perhaps both, will be of considerable duration.

The mercury falling considerably in autumn, winter, or spring, indicates gales of wind, commonly attended with rain, snow, or sleet; but, in summer, it denotes rain, and probably thunder. The mercury is low with high winds, and still lower if accompanied with rain. If the mercury falls quickly in very warm weather, thunder showers may be expected soon after.

If the mercury be in an unsettled and fluctuating state, the weather has the appearance of being very changeable.

If the mercury has been stationary during several days, its surface must be carefully observed, to ascertain whether it is rising or falling. For this purpose, let the exact figure of the surface of the mercury be observed; then shake the tube a little, and observe if the mercury is more or less convex or concave. If it is more convex, it is a sign the mercury is rising; if the same as before, it is stationary; but if less, that it has attained its greatest altitude at that time, and will fall soon. If the mercury was concave before the tube was shaken, and more concave afterwards, the mercury is falling; if of the same concavity, or nearly so, it is stationary; but if less concave it is rising.

Between the tropics, there is little variation in the height of the mercury in the barometer; and the more distant any place is from the equator, the greater is the range of the mercury. Thus, at St. Helena, the extreme variation is very little; at Jamaica it is only about three tenths of an inch; at Naples it seldom exceeds an inch. In England the extreme range amounts to about $2\frac{1}{2}$ inches; and at Petersburgh to $3\frac{1}{3}$ inches nearly.

SUPPORTS FOR MINERALS BEFORE THE BLOW-PIPE.

Some time ago, Mr. Smithson published an interesting paper on this subject, in the Annals of Philosophy, in which he recommends the use of a mixture of water and clay, instead of water, saliva, or gum-water, generally used. A little of the moist clay is to be taken up on the end of the splinter of sappare; and the particle to be heated being touched by it adheres, the whole is laid aside for a few minutes, and is then dry, and may be heated. Mr. Smithson also recommends small triangles, or slender slips of baked clay, in lieu of sappare, which is not always to be had. Another more recent process is, to file the very end of a platina wire flat, place the minutest portion of the moist clay on it, and then touch the particle to be heated. In a few moments it is dry, and may be put into the flame without flying off, unless too much clay has been taken.

Lieut.-Col. Totten, of the United States, has lately published some experiments on the same subject. His process is a modification of that adopted by Mr. Smithson.

" Not being able," says he, " to obtain any clay sufficiently refractory for my purpose, though I tried the German and the English (Stourbridge) clay, used for crucibles by glass-blowers, and two or three specimens called pipe-clay, I had recourse to the minerals which I designed to expose to the action of the flame: this is Mr. Smithson's third process. Instead, however, of taking upon the point of the wire a very minute portion of the paste made of the powdered mineral, according to Mr. Smithson's method, I formed a paste by mixing the powder with very thick gum-water, and rolling a little of it under the finger, formed a very acute cone, sometimes nearly an inch in length, and generally about a twentieth of an inch in diameter at the base. These cones, being held by the forceps, or attached to the end of a wire, or even of a splinter of wood, may be directed accurately upon the minutest visible particle; and being a little moistened at the point with saliva, the particle will adhere to the very apèx under the strongest blast of the blow-pipe.

" I conceived, that when a very small quantity of paste was used, the extremity of the wire or forceps must necessarily abstract much heat from the fragment under examination, because it must itself be often within the limits of the blue flame; and my object was, as much as possible, to insulate the fragment. These cones need not, in fact, be more than one-quarter or one-fifth of an inch in length; for so effectually is the conducting property of the mineral substance destroyed, by destroying the continuity of its particles, that one of these cones, of the length of half an inch, may be held at the base by the fingers with impunity, while the apex is in the focus of heat.

" One great advantage of this method over the others is, that if fusion ensues, it is owing entirely to the nature of the substance experimented upon, and not in any degree to the agency of foreign substances acting as fluxes."

(Annals of the Lyceum of Natural History, New York.)

REMARKS ON DIFFERENT HYPOTHESIS RESPECTING THE MOON, AND VARIOUS PHENOMENA OF THAT PLANET.

We make no apology for submitting to our readers the subjoined extracts from a highly ingenious and interesting work, entitled SELENOGNOSTIC FRAGMENTS, published by Dr. Gruithuisen, whose name ranks deservedly high in the list of foreign astronomers.

No body in the starry heavens, observes the Doctor, in his introduction, excites more general interest than the faithful satellite of the earth: in fact, its surface presents, even to the naked eye; objects so varied, that it instantly inspires the spectator with a wish to inspect this unknown world, with the aid of a powerful telescope. But what especially prompts us to study the physical properties and constitution of the moon, is the expectation of discovering an analogy common to all the great bodies of the universe, with respect to their organization. This, he adds, is what has hitherto been the foundation of my celestial observations, being myself convinced that we shall never attain to any excellence in the study of geognosy, till we have discovered this analogy. It is with this intention that the auther has surveyed, examined, and studied many chains of terrestrial mountains; and it is with this view that he publishes the particular appearances, which eight years observations have enabled him to remark upon the surface of the moon.

To render his work more intelligible to his readers, the Doctor has inserted a lithographic general map of this planet; for which purpose he has consulted Mayer's draught of the moon, and the special maps given by Schrœter in his Selenographic Fragments. Nor has he neglected to avail himself of his own observations. He likewise cites the lunar map of Lambert, and refers to a memoir of that philosopher in the first volume of the Berlin astronomical almanack.

Atmosphere of the Moon. Cassini, Louville, Bianchini, Carbone, Euler, Krüger, Boscovich, Ulloa, Dusejour, Wolf, and Halle, maintain the existence of a lunar atmosphere; while Mayer, Grandjean de Fouchy, De l'Isle, and De la Hire, deny it. Without dwelling upon the reasons and observations which, before the invention of achromatic telescopes have been alleged on both sides of the question, Doctor Gruithuisen confines himself to the direct proofs drawn from the discoveries of Schrœter. The latter has calculated the elevation of the twilight observed by him in repeated observations on the increasing moon. This elevation agrees in a surprising manner with the theorem of Melanderhielm; namely, that on the surface of planets the density of their atmosphere is in proportion to the squares of the weight of the bodies. This proportion had been suggested to Newton by that of the squares of weights on the surface of the moon, and the surface of the earth.

In fact, this latter proportion being as 1 to 28·40, is almost equal to the result of Schrœter, who found that the lunar atmosphere is 28·94 times less dense than our own. Hevelius, De Luc, and many other philosophers, have thought that the air on the surface of planets was only ether condensed, and have considered ether, in its turn, as rarefied air, an opinion, which, in a theoretical point of view, confirms the theorem of Melanderhielm.

To attempt to combat this theory, adds our author, would have the effect of entangling us in a multitude of inextricable difficulties; for we must then affirm that ether and air have no communication together; that, consequently, they cannot mix, and that there is between them a kind of barrier, as if our earth was enclosed in a globe of hollow glass: yet we know that all gases mingle together, which, moreover, must happen from the pressure of our air upon ether, and, reciprocally, on account of the rapid motion of the earth. It is to this pressure that M. de Zach attributes the diurnal oscillations of the barometer, observed at the equator by Humboldt. We should likewise be obliged to affirm, that as the air of planets is essentially different from ether, there can be no affinity between them, and consequently that no body can burn in ether for want of oxygen, a conclusion not warranted by observations, since shooting stars and meteors burn and shine at a height at which in general the presence of atmospheric air is not supposed. For example, in 1795, Schrœter saw, with his reflecting telescope of 20 feet long, a shooting star, the height of which he estimated at more than four millions of miles. If then it be admitted that each body of the universe, by the influence of a weight proportioned to its bulk, forms out of ether, the atmosphere by which it is surrounded, then the moon must also borrow from ether its portion, which becomes condensed and forms its atmosphere. The existence of water in the lunar atmosphere can no longer be questioned, for clouds have been seen upon its surface, as is proved by the almost innumerable observations of Schrœter, to whose work the Doctor refers for more extensive details.

Organised Beings in the Moon. It is a remarkable circumstance, observes M. Gruithuisen, that all those who can take what may be termed a cursory survey of the moon through a telescope, consider it as a desert and globe, upon which nothing lives or grows: on the contrary, others, who have explored its surface for many years, speak of it, as if organised beings could not fail to exist there.

Shrœter conjectures the existence of a town towards the north of *murius* (a lunar spot), and the canals which are observable towards *hyginus* (another spot), and which, after disappearing in some places, are again perceived in others (a thing, says Dr. G. of which I have convinced myself), appear to him very advantageous for the commerce of the *Selenites:* finally, he represents a part of the spot named *mare imbrium* to be as fertile as Campania.

The ancients supposed the moon to be inhabited. Orpheus, Anaxagoras, Zenophon, and Pythagoras, are of this opinion. Their strength of reasoning compensated, in this instance, for their want of telescopes: even Plutarch entertained the idea, that the obscure places on the moon's surface were seas, which could not reflect the light of the sun. More recently, Kepler, Duhamel, and many others have been of the same way of thinking respecting the existence of the *Selenites.* Indeed, so general has this sentiment been, that even the American savages have believed the moon to be inhabited.

In latter times, some persons have considered the too great rarefaction of the air as an insuperable obstacle to peopling the moon. Without doubt, says our author, this circumstance would not fail to alarm more than one philosopher of a delicate constitution, particularly when he knows that neither raisins nor apricots are to be found even on Chimboraço. Others, on the contrary, have not forgotten that M. Guy-Lussac ascended, with his balloon, to a height greater by 2000 feet than the height of that mountain. So that an inhabitant of our globe, if placed in the lowest regions of the moon, might find himself very ill at his ease, but not so much so as to cause his death.

While speaking of the inhabitants of the moon, we may observe, that some theorists have affirmed that no animated beings could exist on that planet, but such as were capable of eating stones, doing without drink, living on a scanty supply of air, and supporting the extremes of heat and cold. These particulars, adds Mr. Gruithuisen, may be considered as a summing up of all the doubts that have arisen on the question whether the planets are habitable or not. He then discusses each of these points. He thinks he can confidently affirm that the moon has vegetables and animals to serve for food to its inhabitants: he even goes so far as to indicate some of their genera and species. In the absence of wine, he continues, the *Selenites* have water, so that they possess the means of quenching their thirst. They are likewise supplied with air in more than sufficient quantity, only that this air is extremely rarefied. If we admit of lakes and seas in the moon, why should they not contain shell and other fish, and amphibious beings? And that man can accustom himself to a highly rarefied atmosphere, has been shown by the aerial ascent of M. Guy-Lussac, already referred to. According to Humboldt, the atmosphere supports a column of quicksilver of only twenty inches at Quito; of eighteen inches at Micuipampa, and of seventeen inches in the latitude of Antisana, all inhabited places upon the earth, notwithstanding this rarefaction. Lastly, the *Selenites* can face the cold and heat with the assistance of fire, which they have the means of procuring in the former case; and in the latter, by means of the deep caverns, in whose coolness they can obtain refuge from the heat.

Waters in the Moon. By these, says our author, I understand all the springs, rivers, lakes, and seas. After having collected and discussed at great length all the facts calculated to illustrate the subject, he thinks he has a right to ask, who can now bring forward any probable argument against the existence of lakes in the moon? But, he adds, lakes presuppose rivers, or at least simple rivulets or springs, their existence is then sufficiently demonstrated.

Of the Lunar Structure. The interior structure of the moon is probably not different from that which is common to all the bodies of the universe; namely, concentric beds formed by the accumulation of successive strata.

Of the Exterior Structure or Constitution. This consists properly in the chains of mountains; the caverns, the declivities and the acclivities are immediate consequences of this disposition.

We shall only add a few words relative to the lithographical map which Doctor Gruithuisen has attached to his work, for the purpose of facilitating the discovery of the points, which he more particularly wishes to designate upon the face of the moon. To accomplish this, he indicates their situation by their distance from two lines, which may be said to represent the equator and the first meridian of the moon, which we consider to be a felicitous and useful imitation of terrestrial longitudes and latitudes.

SOLUTIONS OF QUESTIONS.

QUEST. 61, *answered by* an anonymous Correspondent.

As 1 h. : 12 m. : : 34 s. : $36\frac{4}{15}$ r. + 5 = $41\frac{4}{15}$, then the hound gains 8 miles per hour: as 8 m. : 1 h. : : $41\frac{4}{15}$ r. : $58\frac{1}{32}$ s. the time the hound would be in catching the hare. And as 1 h. : 20 m. : : $58\frac{1}{32}$ s. : $103\frac{1}{6}$ r. the distance. Then $58\frac{1}{32}$ s. = time, and $103\frac{1}{6}$ rods = distance.

This question was accurately solved by Mr. J. HARDING and Mr. PHILIP MUNIS; but we prefer the above on account of its arrangement.

QUEST. 60, *answered by* Mr. W. TAYLOR *(the Proposer)*.

Let t equal the whole time of the descent, then will $t-1$ be the time of descent through the first half of the tower's height, and therefore we have $t^2 : (t-1)^2 :: 2 : 1$, whence $t^2 - 2t + 1 = \frac{t^2}{2}$, which reduced, gives $t = 2 + \sqrt{2} = 3{\cdot}414$ seconds for the time, and the tower's height is 187·48 feet.

We received two other solutions to this question from intelligent and old Correspondents; but they were both erroneous.

QUESTION FOR SOLUTION.

QUEST. 63, *proposed by* Mr. WHITCOMBE, *Cornhill.*

In a given quadrant of a circle to inscribe geometrically a rectangle, whose length and breadth shall be in the ratio of m to n; and to give a geometrical demonstration.

QUEST. 64, *proposed by* Mr. J. TAYLOR, *Clement's-lane.*

John goes with a message from Charing Cross to the India House, and Peter with a message from the India House to Charing Cross: they start at the same instant of time; both travel uniformly, and in such proportion, that John, 20 minutes after their meeting, arrives at the India House; and Peter, in 45 minutes after their meeting, arrives at Charing Cross. From this data I demand the respective times occupied in the journies of John and Peter?

PNEUMATICS.

AIR AS THE VEHICLE OF HEAT AND MOISTURE.

The earth and the atmosphere, taken generally, receive at all times nearly the same quantity of heat and light from the sun.

As the whole of one side of the earth is constantly turned to the sun, the only difference in the quantity of heat and light which the earth receives in a given time, must arise from the changes which take place in its distance from the sun at different seasons of the year. In consequence of these changes, the quantities of light and heat received by the earth are not proportional to the times, but to the angles described by the earth round the sun in those times. These variations, however, are but inconsiderable; and as they are annual, they do not produce any inequality in the whole heat or light of one year, compared with those of another.

Though the earth is thus receiving heat continually, and nearly at the same rate, its average temperature appears to remain invariable; as much heat as comes from the solar rays, flying off continually into the fields of vacuity or of ether.

While the general temperature of the earth remains invariable, the distribution of heat over its surface is extremely unequal, being different in different places, and in the same place subject to variations, both regular and irregular.

The causes that determine the distribution of heat over the earth's surface, are either the direct influence of the solar rays, or the communication of heat by the air from one part of the earth's surface to another.

The first of these depends on the latitude of the place, or its distance from the equator, by which the intensity of the heat and light from the sun, and also the length of the day, are determined for different seasons of the year.

The intensity of the sun's rays, when they strike on any plane, is as the quantity that falls on a given space, or as the sine of the sun's elevation above the plane. The nearer the sun is to the zenith of any place, at a given moment, the greater the intensity of heat produced by his rays.

The heat for an entire day depends also on the length of the day; and as the day is longer where the distance from the zenith is greater, the inequality in the distribution of heat arising from the one of these causes, compensates that proceeding from the other, and brings their combined effects nearer to an equality than might be imagined. FONTANA has shown, that the heat of the day of the summer solstice at Pavia, is greater than the heat of the same day at Petersburg only in the ratio of 63° to 62°, though the latitude of the former be 45° 11′, and of the latter 59° 56′.

The same author finds, that when the sun's declination exceeds 18°, or from about the 10th of May to the 30th of July, the heat in twenty-four hours proceeding from the sun's rays, is greater at the north pole than at the equator.

The distribution of heat, therefore, if only the direct influence of the sun were to act, would be very different from that which takes place in nature.

The intensity of the solar heat is less in low elevations than is here supposed, on account of the rays coming through a larger mass of air, and of air more loaded with vapour, so that a great quantity of them is intercepted.

The effects of the direct influence of the sun, are greatly modified by the transportation of the temperature of one region into another, in consequence of that disturbance in the equilibrium of the atmosphere, which the action of those rays necessarily produces.

In order that there may be an equilibrium in a fluid like the air, every stratum of air that is level or horizontal all round, ought to be of the same density. It ought, therefore, also to be everywhere of the same temperature, which not being the case, the constant motion of the air is the necessary consequence of heat being unequally distributed. The columns of air that are lighter, are displaced by those that are heavier, and hence a general tendency in the air to move from the poles toward the equator. This general tendency, which is calculated to moderate the extremes of temperature, is also greatly modified by local circumstances.

The sea is preserved of a moderate temperature, by the statical principle that makes the heavier columns of a fluid displace the lighter. A more uniform temperature is thus given to the sea, which communicates itself to the air incumbent on it, and to that on every side.

Conversely, the effect of great and unbroken continents is favourable to the extremes of heat or of cold.

The constitution of the surface may tend to increase and sometimes to diminish this effect. High mountains especially, if covered with snow, may enforce the rigour of a cold climate, or temper the heats of a warm one.

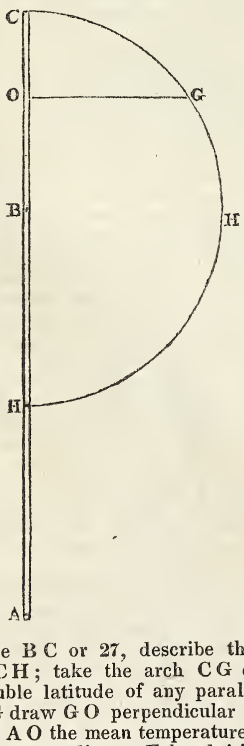
Forests tend to increase the cold, by preventing the sun's rays from striking the ground. Evaporation produces cold; and marshes and lakes are therefore favourable to the severity of the weather. The congelation of water produces heat, and moderates the cold; the melting of ice, on the other hand, increases the capacity for heat, and so produces cold.

Height above the level of the sea, causes a diminution of heat, at the constant rate of about 1° for 270 feet nearly, when not far from the surface of the earth.

It has already been remarked, that this decrease seems to be somewhat slower as we ascend, but not very considerably, as far as our observations have extended.

The combination of these causes gives to every place a mean temperature, which remains always nearly the same, and which decreases from the equator to either pole, according to a law that has been determined by observation.

This mean temperature may be determined by a geometrical construction, as follows: Divide the line A C into equal parts numbered from A, so as to represent the scale of a thermometer, let A C be made equal to 85, and A B to 58 of those parts. Then from the centre B with the



distance B C or 27, describe the semicircle C H; take the arch C G equal to the double latitude of any parallel; and from G draw G O perpendicular to A C; then is A O the mean temperature of that parallel, according to *Fahrenheit's* scale.

The mean temperatures thus found, agree very well with observation. Springs, in which the water does not considerably change its heat from one season of the year to another, afford an expeditious and accurate way of ascertaining the mean temperature.

On ascending into the atmosphere at a certain height in every latitude, a point is found where it always freezes, or where it freezes more than it thaws, so that the mean temperature is below 32°. The curve joining all these points from the equator to the pole, is called the line of perpetual congelation. (See page 110, vol. i.)

The temperature of the latter end of April is observed, at least in the temperate zone, to be nearly the mean temperature of the year. From the time the heat increases, and is at its maximum about the 21st of July, it goes on decreasing from that time till it come to the mean in the end of October, and passes from thence to the greatest cold about the 21st of January.

As we go eastward from the shores of the Atlantic, the mean temperature of any parallel becomes lower at a rate that may perhaps, for the north part of the temperate zone, be estimated at a degree for 150 miles.

At St. Petersburgh, lat. 59° 56′, about 750 miles from what may be accounted the shores of the Atlantic, the temperature is 5° 5′ below the standard. The medium temperature of January is no more than 10°. By computation, it ought to be greater than 32°. The winter lasts from October to April, and the cold is sometimes as great as the freezing point of mercury, or—39°. From a mean of several years, the mean of the winter cold is —25°.

It was at Krasnojark, lat. 56° 30′, long. 93° E, that mercury was first known to freeze by natural cold.

At Irkutz, lat. 52° 15′, long. 105° east, the mean temperature from October to April has been known to be as low as —6° 8′, a temperature which for severity and duration, exceeds any thing that has yet been observed elsewhere.

This increase of the severity of the winter, and the consequent diminution of the mean temperature on going eastward, holds in all the latitudes north of the parallel of 30°; but the diminution is slower as we approach that parallel; to the south of 30°. the mean heat increases on retiring from the ocean.

This diminution takes place all the way to the shores of the Pacific, or very near them. The climate of Pekin is vastly more severe than that of the same parallel (39° 54′) in Europe.

In the new Continent also, at least in the part of it to the north of the Tropic of Cancer, the mean temperature is much below the standard, and the severity of the winter much greater than in the same latitudes in Europe.

At Prince of Wales' Fort, Hudson's Bay, lat. 59° long. 92° west, the mean temperature is 20° under the standard; at Nain, in Labrador, 16°; at Cambridge, in New England, (lat. 42° 25) 10 degrees. Mercury has been supposed to be frozen by the natural cold as far south as Quebec, lat. 47°.

A very low mean temperature, and extreme cold in winter, are characteristic of the climate of North America.

In the higher latitudes of the southern hemisphere, the temperature is lower than in the same latitudes of the northern hemisphere.

The south pole is surrounded to the distance of 18 or 19 degrees with a barrier of solid ice, through which even the skill and intrepidity of Captain Cook could not force a passage.

It is known also, that detached masses of ice float down in that hemisphere, as low as the latitude of 46°. The cause of this phenomenon is by no means sufficiently understood. The varieties of temperature to be met with on the surface of the earth, appear to be confined within the limits of 100° and —40°.

No degree of cold much below —40° has ever been observed in nature, even when thermometers have been employed, containing a fluid not liable to congelation.

The heat of 100° is rare; but a heat approaching to 90°, is found in the summer of most countries within the limits of the temperate zones.

There is hardly any climate, even in the frigid zone, where a temperature between 60° and 50° is not occasionally experienced.

The greatest heat is much less above the mean temperature, than the greatest cold is below it. The mean temperature for the whole surface may be taken at 58°; the greatest summer heat is only 42° above this; the greatest winter cold is 98° under it.

There is reason to think that the climates of Europe were more severe in ancient times than they are at preseut; and the change that has taken place, may with great probability be ascribed to the better and more extensive cultivation of the ground.

Cæsar says, "that the vine could not be cultivated in Gaul, on account of the severity of the winter." The rein-deer was then an inhabitant of the Pyrenees. The Tiber was sometimes frozen over, and the ground about Rome covered with snow for several weeks together.

Cultivation may improve a climate. 1st, By the draining of marshes and lessening the evaporation, which is so great a cause of cold. 2d. By turning up the soil and exposing it to the rays of the sun. 3d. By thinning or cutting down forests, which by their shade prevented the penetration of the sun's rays. The improvement which is continually taking place in the climate of North America, proves that the power of man extends to the phenomena, which, from the magnitude and variety of their causes, seemed most superior to his controul. At Guiana, in South America, the rainy season has been shortened by the clearing of the country, and the warmth greatly increased. It thunders continually in the woods; rarely in the cultivated parts.

OF RAIN.

The vapour that rises from water uniting itself to the air, ascends into the higher regions of the atmosphere, and is carried by the winds to great distances.

It cannot be doubted, that the humidity raised in this manner, is chemically dissolved in the air.

The humidity does not lessen, but increases the transparency of the air, and cannot be withdrawn from it, but by substances that attract it powerfully.

The power of air to dissolve humidity, increases in a greater ratio, than that in which its temperature increases.

It appears from Saussure's experiments, that while the temperature increases in arithmetical progression, the humidity which the air is able to contain, increases in geometric progression. A cubic foot of air, of the temperature 66°, is able to hold in solution 11 or 12 grains of water: the air itself weighs 570 grains; to that air of the temperature 66°, dissolves about a 50th of its own weight of water.

Hence, if two portions of air, of different temperatures, and both saturated with humidity, be mixed together, a precipitation of humidity must necessarily take place.

If, therefore, large portions of the atmosphere, of different temperatures, and saturated, or nearly saturated, with humidity, be driven against one another by contrary winds, the consequence must be a precipitation of humidity, or the formation of clouds.

The mixture of different portions of air is likely to take place most frequently, when the two opposite currents already mentioned, come in contact with each other. This is at the height of 18000 feet and upwards, which argees very well with the medium height of the clouds.

The clouds thus formed have their particles united into larger masses or drops by different causes, such as the mutual attraction of aqueous particles, the force of the wind, or the operation of electricity, and so fall down in rain on the surface of the earth.

The intimate connection between rain and the existence of different currents of air, is evident from many appearances. Some of which we shall state.

1. When the trade winds blow uniformly, hardly any rain falls; but when the monsoon changes, heavy falls of rain seldom fail to take place.

2. In the tropical climates, the rainy season is always on the sun's approach to the zenith, at which time also the winds are most variable.

3. There are some spots of continual rain, which seem to be where opposite streams of air constantly meet one another.

4. There are several tracts on the earth's surface where it hardly ever rains. They are usually far inland, and have extensive plains, without any of those inequalities of surface that promote the mixture of air.

5. In the midst of those desarts, where mountains occur, moisture is precipitated sometimes in the form of rain, but most frequently of dew, so that there are springs of fresh water, and great fertility produced.

6. There is in our climate hardly any instance of rain without a change of wind, and very rarely a change of wind without rain in a greater or smaller quantity.

7. The lowness of the mercury in the barometer is a sign of rain. It is a certain indication of the subversion of the equilibrium of the atmosphere; and makes it probable, that before the equilibrium of the atmosphere is restored, winds from different quarters, and of different temperatures, must come into collision with one another.

The vapour raised up into the air, is of a quantity sufficient to afford all the rain that falls, or to supply all the springs, and of consequence all the rivers derived from them on the surface of the earth.

Dr. Halley shewed, that the evaporation from the sea alone is a sufficient supply for all the waters that the rivers carry into it. His calculation was founded on a very complex view of the subject, and liable to several objections. Buffon took a more simple view of the matter, by selecting one of those lakes that sends out no stream to the ocean, and shewing that the probable evaporation from the surface of the lake, is equal to all the water carried into it.

A simpler view still may be taken, by showing that all the water annually emptied by a river into the sea, is less than the rain that falls on the surface drained by it. Thus, according to Dr. Halley's computation, the water which the Thames carries down through Kingston Bridge, to which the tide does not reach, is 25344000 cubic yards, or 684288000 cubic feet per day, which gives 249765120000 cubic feet, for the quantity of water which the Thames discharges annually into the sea. Now, the surface drained by the Thames and its branches, appears to be about equal to a circle of 40 miles radius; that is, nearly to 5036 square miles, or 140395622400 square feet. But if we suppose that the depth of rain that falls annually, at an average over this surface, is two feet, we have a quantity which exceeds that carried down by the Thames by 31026124800, or nearly an eighth part of the whole, which is therefore left to be taken up by the evaporation.

The disputes that prevailed so long concerning the origin of fountains and rivers, chiefly arose from the difficulty of conceiving how a precarious and accidental supply could be rendered equal to a regular and great expenditure.

The quantity of rain that falls in different places in the same year, and in the same place in different years, is extremely various; and even in the temperate zone, runs between the extremes of 18 and 100 inches.

In places not very distant from one another, the difference in the quantity of rain is often very great. The neighbourhood of the sea on one hand and mountains on the other, is most favourable to the production of rain; from the first is derived a humid atmosphere, and from the second the prevalence of winds of different temperatures.

The region of the air in which the precipitation of humidity takes place, is frequently one where the temperature is below freezing; the frozen particles then uniting, as in the case of melted vapour, form flakes of snow, which reach the surface in that same state, when the cold of freezing continues down to the surface.

When the aqueous particles first form a drop, and are afterwards frozen in their descent, they become hail, which is sometimes found crystallized with some degree of regularity. The whiteness and opacity of the hail, is probably owing to the congelation being performed where the air is very rare.

Professor Leslie has remarked, in the curious experiments he has made on the production of ice by evaporation, in a receiver where the air was considerably rarefied, that the ice is more porous and less transparent, than that which is formed under the ordinary pressure of the atmosphere.

Dew is a precipitation of humidity from the lower strata of the atmosphere, which does not disturb the transparency of the air, and to which the mixture of different streams of air does not seem necessary.

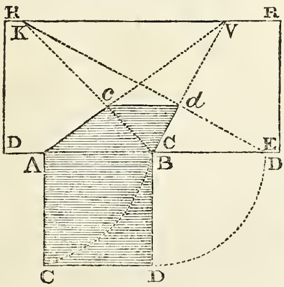
Dew is only formed in calm weather, and in the evening or during the night. The resting of the globules of dew on the points of grass and other plants, seems to indicate the presence of some electrical influence. Bruce has remarked, that during the dry season no dew falls in Egypt, but that it is usually observed in the Delta five or six days before the inundation.

Besides these deposits from the atmosphere, which are all of one substance, there are others that cannot be traced to the same origin. These are the stones which have often been said, and have of late years been ascertained beyond all doubt, to fall down from the air: on examination, they are found to contain certain metallic ores, in many respects unlike to any thing that is found, either on the surface or in the bowels of the earth.

PERSPECTIVE.

To exhibit the Perspective Appearance of a Square seen obliquely, and having one of its Sides in the fundamental Line.

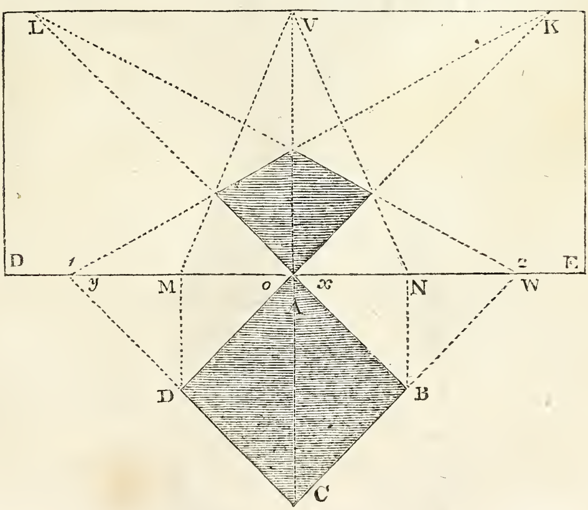
Let ABCD be the square, having the side AB in the fundamental line;



the square being viewed obliquely, assume the principal point V in the horizontal line HR, in such a manner as that a perpendicular to the fundamental line may fall without the side of the square AB; at least, may not bisect it; and make VK the distance of the eye. Transfer the perpendiculars AC and BD to the fundamental line DE; and draw the right lines KB, KD, as also AV, VC. Then will A and B be their own appearances; and *c* and *d* the appearances of the points C and D. Consequently A *c d* B is the appearance of the square ABCD. If the square ACBD should be at a distance from the fundamental line DE; which rarely happens in practice, the distances of the angles A and B must likewise be transferred to the fundamental line, as is evident from the preceding problem. And since even the oblique view is not very common; in what follows we shall always suppose the figure to be posited directly opposite to the eye, unless where the contrary is expressly mentioned.

To exhibit the appearance of a square, whose diagonal is perpendicular to the fundamental line.

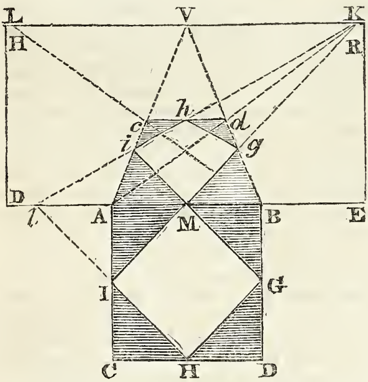
Let ABCD be the square, having its diagonal AC perpendicular to the fundamental line.



Continue the sides D C and C B till they meet the fundamental line in 1 and 2. From the principal point V set off the distance of the eye to K and L. From K to A and 1, draw right lines K A and K 1; and from L to A and 2, the right lines L A, L 2. The intersections of these lines will exhibit the appearances of the square A B C D viewed angle-wise.

To exhibit the appearance of a square, having another inscribed in it.

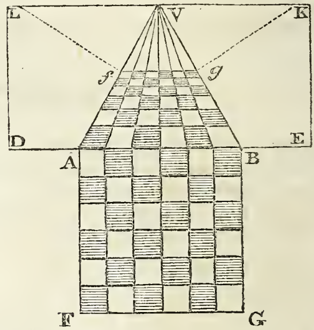
Let the square A B C D, which inscribes the square I M G H, have its side A B in the fundamental line, and the diagonal of the less perpendicular to it.



From the principal point V, set off, each way, on the horizontal line H R, the distances V L and V K; draw V A and V B; and K A and L B; then will A *c d* B be the appearance of the square A C D B. Produce the side of the inscribed square I H, till it meet the fundamental line in 1; and draw the right lines K 1, and K M; then will *i h g* M be the representation of the inscribed square I H G M. Hence is easily conceived the projection of any figure inscribed in another.

To exhibit the perspective of a pavement, consisting of square stones viewed directly.

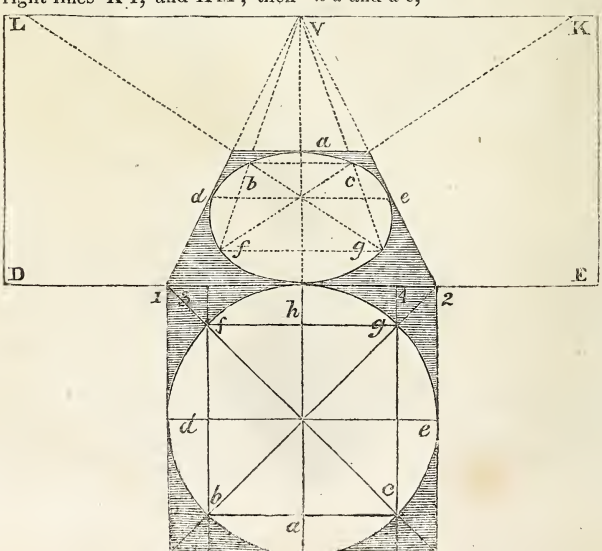
Divide the side A B transferred to the



fundamental line D E into as many equal parts as there are square stones in one row. From the several points of division, draw right lines to the principal point V; and from A to the point of distance K, draw a right line A K; and from B to the other point of distance L, draw another L B. Through the points of the intersections of the corresponding lines, draw right lines on each side, to be produced to the right lines A V and B V. Then will A *f g* B be the appearance of the pavement A F G B.

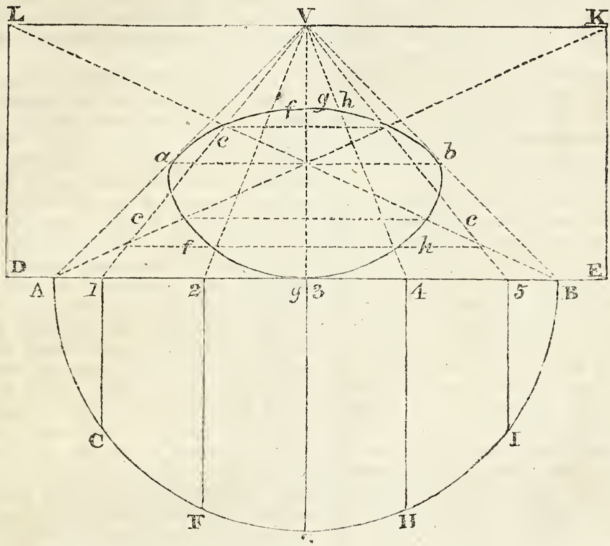
To exhibit the perspective of a circle.

If the circle be small, circumscribe it by a square. Draw diagonals and diameters *h a* and *d e*,



intersecting each other at right angles; and draw the right lines *f g* and *b c* parallel to the diameter *d e* through *b* and *f*; as also through *c* and *g* draw right lines, meeting the fundamental line D E in the points 3 and 4. To the principal point V draw right lines V 1, V 3, V 4, V 2; and to the points of distance L and K, draw the right lines L 2 and K 1. Lastly, connect the points of intersection *a, b, d, f, h, g, e, c,* with arches *a b, b d, d f,* &c. Thus, will *a b d f h g e c a,* be the appearance of the circle.

If the circle be large, on the middle of the fundamental line A B,



describe a semicircle; and from the several points of the periphery, C, F, G, H, I, &c. to the fundamental line, let fall perpendiculars C 1, F 2, G 3, H 4, I 5, &c. From the points A, 1, 2, 3, 4, 5, &c. draw right lines to the principal point V, as also a right line from B to the point of distance L; and another from A to the point of distance K. Through the common intersections, draw right lines as in the preceeding problem; thus shall we have the points *e, f, g, h, i,* which are the representations of these, A, C, F, G, H, I; and these being connected as before, give the projection of the circle.

Hence appears, not only how any curvilinear figure may be projected on a plane; but also how any pavement, consisting of any kind of stones, may be delineated in *perspective.*

Hence also appears what use the square is of in *perspective;* for even in the second case we use a square divided into certain areolæ, and circumscribed about the circle; though it be not delineated on the geometrical plane in the diagram.

We may here observe, that if the magnitudes of the several parts of an object be given in numbers, together with the height and distance of the eye, the figures of the object is first to be constructed by a scale geometrically; and the fundamental point, with the point of distance to be determined by the same scale. We may also observe, that it is not necessary that the object be delineated under the fundamental line: in the projection of squares and pavements, it is best not. But where it is necessary and space is wanting, draw it apart; find the divisions in it, and transfer them to the fundamental line in the plane.

Threads being hung on the principal point, and the point of distance, and thence stretched to the points of the divisions of the fundamental line; the common intersections of the threads, will give the projection of the several points without confusion; a thing much to be feared from the multiplicity of lines to be drawn.

CHEMISTRY.

Mercury is always fluid when in a pure state, and is one of the most brilliant and shining of all known metals. When its surface is sufficiently clear, it forms a very fine mirror. Its colour is as beautiful as that of silver, with which it has always been compared. After platina and gold, it is considered as the heaviest of all known bodies. Its specific gravity is 13·568, taking water at 1·000.—Authors were formerly very particular in observing, that all the most ponderous substances swam upon its surface, whilst gold alone sunk in it; at the present day we have to add to this, platina and tungsten

Boerhaave asserted, in his Elements of Chemistry, that mercury could not be rendered solid by any degree of cold, though he admits a condensation of $\frac{1}{269}$ of its primitive volume; a circumstance which cannot take place in its real congelation. This assertion of Boerhaave, and other philosophers who have followed him, was proved to be false in the year 1759; in which year the academicians of Petersburg, availing themselves of an intense degree of natural cold, augmented it still further by a mixture of snow and fuming nitrous acid; the mercurial thermometer which they used descended to 213 degrees of De Lisle's scale, which corresponds with 46 below 0 of that of Fahrenheit. As the mercury did not descend any lower, but seemed stationary, the academicians broke the glass bulb of their instrument, in which they found congealed mercury, that formed a solid substance susceptible of being extended by the hammer. They thus discovered that mercury might become solid, and that in this state it possessed a certain degree of ductility. They remarked, that at every stroke of the hammer, the pressure, developing the caloric in the interior of the metal, fused it, and that it ran into globules.

This first experiment was, in some measure, nothing more than a hint to philosophers concerning a property unknown, and till then even denied, in mercury; it has since been often repeated, and of late it has become as easy and simple an experiment as most of those that are made in Chemistry. In the year 1772, Pallas caused mercury to congeal, at Krasnejark, by a natural cold of —55½ deg. of Fahrenheit's scale. It was observed that it then resembled soft tin; that it could be flattened; that it broke easily; and that its fragments, when brought into contact, were glued or soldered together, as happens in all other softened metals. However, it is evident that he did not obtain its real conversion into a solid, or complete concretion, as the mercury was still soft, and only in a state of semi-congelation. In the year 1775, Mr. Hutchins observed the same congelation at Albany Fort, and Mr. Bicker at Rotterdam, in 1776, at 56 deg. below 0. In the year 1783, the congelation of mercury was effected in England with a less degree of cold; and Mr. Cavendish has proved 31½ below 0 of Reaumur's, or 40 below Fahrenheit's thermometer, to be the real degree at which it takes place.

As a metal always fused, always liquid at the temperature of our climate, mercury constantly affects the form of perfect globules when it is divided. When inclosed in a glass phial or tube, its surface is convex, which depends upon the small attraction which it has for the glass; in fact, if we pour it into a vessel or tube of some metal with which it is able to combine, instead of remaining convex, its surface becomes concave. As this round, curved, and convex surface may give rise to some errors in barometrical observations, especially in those which are made with tubes of a fine bore, in which the elevation of the mercury ought to be an exact measure of the height of the places which we wish to determine, attempts have been made to obviate this source of error, by rendering the mercurial surface flat. Cassebois succeeded by boiling the mercury for a long time in the barometrical tubes; by which means a surface almost perfectly horizontal was obtained, especially in tubes of a wide bore.

The expansion of mercury by the action of fire has not yet been very accurately determined; it is known to be a very good conductor of caloric, on which account it appears very cold to the hand when immersed in it; and it is also owing to this conducting property that a red hot iron, when plunged into mercury, instantaneously loses its redness, which it would have retained for some time in the air, and even in water. Its expansion by heat proceeds in a very uniform manner; and it is on this account that it is employed in the construction of thermometers. When it is penetrated with a quantity of caloric, which has not yet been well ascertained, but which is estimated at 656 degrees of Farhenheit's thermometer, the mercury swells, is reduced to the state of vapour, and volatilized. When this experiment is performed in the air, the mercury presently condenses into a white smoke, which is capable of producing very injurious effects upon animals. If it be performed in close vessels, in such a manner that the metal may speedily become fixed and liquefied, this becomes a means of distillation, in which the habitudes of the volatile metal are the same as those of every other distilled liquid. In this operation, which is often employed for the purpose of purifying the mercury, it is customary to adapt to the neck of the retort of iron or stoneware which is used a tube of linen, the extremity of which is immersed in the water with which the receiver is filled. By means of this apparatus, the mercury is speedily condensed into the liquid form, and collected entire under the water, from which it is afterwards separated by rubbing it with paper manufactured without size, drying it in a gentle heat, passing it through a skin, agitating it with very dry bread-crumbs, bran, and other desiccating means of a like nature. It is on account of this easy process of distillation that Chemists have considered mercury as the most volatile of all metals.

Mercury is a very good conductor of electricity and galvanism. Its electrical property is probably the cause of the phosphorescence, and the considerably bright light which it emits, when it is agitated in a vacuum. It has been discovered that this phosphorescence is an electrical phenomenon, which takes place only in consequence of the friction of the mercury against the sides of the tube, and that the mercury does not thereby suffer any sensible alteration.

Mercury is not altered by being kept under water. When exposed to the air, its surface is gradually tarnished, and covered with a black powder, owing to its combining with the oxygen of the atmosphere. But this change goes on very slowly, unless the mercury be either heated or agitated; by shaking it, for instance, in a large bottle full of air. By either of these processes, the metal is converted into an oxide: by the last, into a black oxide; and by the first, into a red coloured oxide. This metal does not seem to be capable of combustion; at least, no method which has hitherto been tried to burn it has succeeded. It is the only metal which may not, by peculiar management, be made to *burn*.

Native mercury, which has been termed virgin mercury, is found in the form of liquid globules, which are very easily recognised by their brilliancy and liquidity. It is commonly found in tender and friable earths and stones, and frequently interposed between the fissures and the cavities of its own orbs, especially of its sulphuret. It is seldom perfectly pure, and frequently contains some other metal with which it is alloyed; but when it is sufficiently liquid, it is considered as pure, or really native. At Ydria, and in Spain, and America, it is collected in the cavities and clefts of the rocks, into which it filtrates from all sides. It is found liquid in argil at Almaden, and in the beds of chalk in Sicily. It is also found in the ores of silver and lead, and even mixed with the arsenious acid, or white arsenic.

Mercury does not combine with the simple incombustibles; but it combines with the greater number of metals. These combinations are known in Chemistry by the name of *amalgams*.

The amalgam of gold is formed very readily, because there is a very strong affinity between the two metals. If a bit of gold be dipped into mercury, its surface, by combining with mercury, becomes as white as silver. The easiest way of forming this amalgam is to throw small pieces of red hot gold into mercury heated till it begins to smoke. The proportions of the ingredients are not determinable, because they combine in any proportion. This amalgam is of a silvery whiteness. By squeezing it through leather, the excess of mercury may be separated, and a soft white amalgam obtained, which gradually becomes solid, and consists of about one part of mercury to two of gold. It melts at a moderate temperature; and in a heat below redness the mercury evaporates, and leaves the gold in a state of purity. It is much used in gilding. The amalgam is spread upon the metal which is to be gilt; and then, by the application of a gentle and equal heat the mercury is driven off, and the gold left adhering to the metallic surface; this surface is then rubbed with a brass wire brush under water, and afterwards burnished.

Dr. Lewis attempted to form an amalgam of platinum, but succeeded only imperfectly, as was the case also with Scheffer. Morveau succeeded by means of heat. He fixed a small cylinder of platinum at the bottom of a tall glass vessel, and covered it with mercury. The vessel was then placed in a sand-bath, and the mercury kept constantly boiling. The mercury gradually combined with the platinum; the weight of the cylinders was doubled, and it became brittle. When heated strongly, the mercury evaporated, and left the platinum partly oxidized. It is remarkable that the platinum, notwithstanding its superior specific gravity, always swam upon the surface of the mercury, so that Morveau was under the necessity of fixing it down.

There are few metallic substances that exceed mercury in utility. In physics, it is employed in its metallic form; in the construction of meteorological instruments, and a great number of machines in the arts; it is employed in the same form for gilding, silvering of glass mirrors, and in metallurgical operations; its solutions are used in dyeing.

In chemistry, it is applied to a great variety of uses, all equally important.

Besides the experiments in which it is employed for demonstrating the principal truths of this science, it has become of indispensable necessity for furnishing the vessels destined to collect, preserve and combine many of the gases.

It is of equal importance for medicinal purposes.

OF COPPER.

Copper is one of those metals which were known in the most early ages of the world, and has at all times been one of the most easy to extract and manufacture. The Egyptians employed it for a variety of uses, and made of it cast figures, remarkable for their elegant form, in the remotest times of their history. The Greeks manufactured it, melted it, cast it, and employed it in various arts. With them it made the base of the celebrated compounds called Corinthian Brass. The Romans likewise manufactured it in great quantity; and it has even been imagined, that the greater number of their utensils were always made with this metal, and very rarely with iron. This circumstance has been urged as a valid proof that they knew little of iron, and were unskilful in manufacturing it.

The alchemists employed themselves much about copper. They called it *Venus*, on account of the great facility it possesses of combining with many substances, particularly with other metals, and because of the sort of adulteration it makes in these compounds.

By representing it by the emblem appropriated to gold, terminated at bottom by the sign of a cross, they considered it as formed chiefly of gold, but disguised and altered by something acrid and corrosive, which rendered it crude. Though, in the different periods of the great revolution, which has changed the face of Chemistry, we cannot find any researches concerning copper that are immediately connected with the annals of this revolution, or have served to lay the foundation of it, yet this metal holds a rank among those substances, of which the properties are better known, and the modifications have been more accurately determined since the establishment of the pneumatic doctrine. In this class of properties, accurately explained by the modern theory, we ought particularly to place its different degrees of oxidation, its solutions in acids and in ammonia, its precipitates from the metallic state to its highest degree of oxidation, and its reduction by various processes. The labours of Berthollet, Guyton, and Proust, have particularly contributed to the accurate knowledge of these last mentioned facts. Our knowledge of this metal has also become much more complete, and the facts concerning it by far more simple, since the discoveries which have been lately made in experimental Chemistry. It holds almost the third rank among metals in this respect. With regard to its elasticity, it holds nearly the same rank. Its ductility has led Guyton to place it in the sixth rank of metals, between tin and lead. It may be reduced into laminæ, or leaves extremely thin, which the wind will blow away. Its tenacity likewise is pretty considerable: a copper wire, one-tenth of an inch in diameter, supports a weight of 299¼ pounds, without breaking. Its strength or resistance to being broken is estimated by Wallerius as nearly equal to that of iron. Its sonorous quality is superior to that of iron, as may be proved by wires of the two metals of equal length and thickness.

This metal is of a fine red colour, and has a great deal of brilliancy. Its taste is styptic and nauseous; and the hands, when rubbed for some time on it, acquires a peculiar and disagreeable odour.

The density of copper is such, that its specific gravity is to that of water as 7·788 to 1·000. This gravity, however, varies according to the state of the metal: when it has only been melted and cast, it is less than when it has been hammered and forged; but after having passed through the mill, and been drawn into wire, it has the specific gravity of 8·878, which is an increase of about one-seventh.

Its power of conducting caloric has not been accurately ascertained, though it is known to be very great. It does not melt till it is very red. Its fusibility has been estimated by Mortimer at 1450° of Fahrenheit's thermometer, and by Guyton at 27° of the pyrometer of Wedgwood. When it is melted and cast into ingot-moulds, that it may cool quickly, it assumes a granulous and porous texture, which shows like a kind of *crumb* in its fracture, and is liable to exhibit many cavities and flaws in its interior parts. If it be cooled slowly, it yields crystals in quadrangular pyramids, or in octahedrons, which arise from the cube, its primitive form. At a temperature above what is required for its fusion, it rises in vapour, and in a visible smoke, as is observed in places where this metal is cast in the large way, and in the chimneys over the furnaces.

Copper is a very good conductor of electricity and galvanism; but its order and power in this respect, compared with that of other metallic substances, has not yet been determined with precision. The acrid and somewhat fetid smell which pretty sensibly characterises and distinguishes copper, is well known to every one. Rubbing the hand a little time on it is sufficient to impart this coppery odour, to which some other phenomena of the organ of smell have even been compared, particularly that of a *cold in the head*.

Copper is pretty abundantly diffused throughout nature. Germany, Sweden, and Siberia, however, are the three countries, where it has hitherto been found in the largest quantity, and which furnish the most to commerce and the arts. The states of this metal in the earth are so various in their appearance, and in their physical properties, that mineralogists have singularly multiplied the species of it: some have admitted fifteen or twenty, though it is difficult to reckon nine or ten really different from each other in their nature. What they have taken for species are only varieties.

Native copper is met with pretty frequently in the interior parts of the earth, where it is even found very pure. It is known by its brilliancy, its red colour, its ductility, and its specific gravity. Most commonly its surface is of an obscure dull and brown red, on account of the slight oxidation it has experienced. Sometimes it is found shining, and as if it had been burnished or polished; but this is much more rare than the preceding. Its form is frequently crystalline and regular; that of Siberia distinctly exhibits the cubic figure.

The places where native copper is most frequently observed, are Siberia, Norberg in Sweden, Newsol in Hungary, and Saint-Bel, near Lyons.

Copper exposed to cold air, and particularly to damp air, soon loses its lustre; it tarnishes, becomes of a dull brown, grows gradually darker, acquires what is called the colour of antique bronze, and at last becomes covered with a sort of green tint, tolerably bright, known to every one by the name of *verdigris*, or *verdet gris*, as the modern French Chemists will have it.

The atmospheric oxygen begins by converting the surface of the metal into brown oxide; this oxidation is favoured and accelerated by water. The carbonic acid soon unites itself with the copper thus oxidized; so that the kind of varnish of antique medals, statues, and utensils of various kinds, which antiquaries prize in them, and which they call *patine*, is nothing but a true super-oxygenated carbonate of copper, very analogous to malachite or mountain green.

This alteration of copper is much more powerful and rapid, if the temperature of the metal be increased. Every one may have observed how quickly the copper tunnels, used for carrying off the smoke of stoves, change their colour from the moment they are first heated, even slightly, in contact with the air: they speedily assume a blueish, orange, yellowish, or brown tinge, which at length becomes wholly of an uniform deep brown over all the surface. These different and very beautiful hues are obtained even by cautiously exposing on burning coals thin plates or laminæ of copper, as well as that which is in light leaves. By this process, leaves of a sort of *foil* are made of various colours, which are chiefly used, after being cut into small pieces, for covering children's toys, to which they are fastened by a kind of mordant or cement, previously applied on them. In fabricating these, the succession of blue, yellow, violet, and brown, may be observed; the last colour too is that which remains, and is permanent.

When the action of fire on copper is strongly urged; when it is thrown, for instance, in the form of fine filings, into a very strong fire, or when it is heated in a crucible to a white heat after having been melted, it burns much more rapidly than in the former cases; it experiences a real conflagration; it even yields a very brilliant green flame. Accordingly, it is employed in the composition of the coloured fires of the smaller kinds of fireworks, particularly those which are called table fireworks. The same effect which is perceptible at the surface of the crucible in which copper, thoroughly fused and very red, if melted and stirred, is produced by sending through this metal, in a small piece, or in wire, or in thin leaves, an electric discharge. It instantly emits a greenish flame, breaks with decrepitation, and is dispersed in smoke or dust in the air. It may be collected on paper, and will be found covered with a reddish brown oxide. It is to this property likewise we are indebted for the green colour which we so frequently see in the flame of various combustible substances, but particularly alcohol, when cupreous salts have been dissolved in it. Notwithstanding the activity of this sort of combustion, and its difference from the slow oxidation already described, the oxide resulting from it uniformly contains but twenty-five parts of oxygen to a hundred of the metal, and completely resembles that which is obtained by the former kind of combustion.

ASTRONOMY.

After the 20th of March the sun appears to rise every day sensibly more to the northward than he did the day before, to be more elevated at mid-day, and to continue longer above the horizon, till the 21st of June, which is the longest day at all places in the northern hemisphere.

At this time the angle formed by the northern half of the earth's axis, and the line joining the centre of the earth and sun is then at the least, which is 66½ degrees. The sun will then appear to touch the tropic of Cancer, and be vertical to all places 23½ degrees north of the equator. This time of the year is called the *summer solstice*, because it is the middle of summer, and the sun seems to remain stationary for a few days.

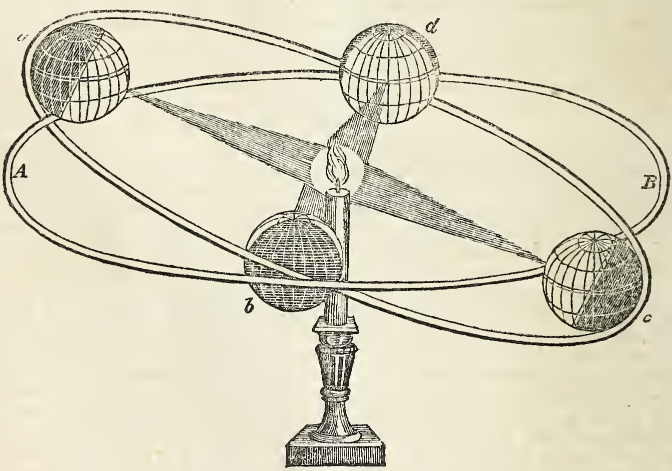
After the 21st of June, the angle joining the centres of the earth and sun gradually increases, and the sun appears to recede from the tropic of Cancer, in the same manner as he advanced to it, rising every day a little farther to the south than he did the day before, till the 23d of September, when the axis has a similar position to what it had on the 20th of March, being again at right angles to the line just mentioned, consequently the days and nights are again equal all over the globe, which constitutes the *autumnal equinox*.

The sun now appears to cross the equinoctial; and the south pole, which, during the last six months, was in the dark, begins to turn towards the sun; and precisely the same phenomena are exhibited to the southern hemisphere, as those already described in the case of the northern half of the earth. On the 22d of December the sun appears to touch the tropic of Capricorn, and is vertical to all those places on the earth that are 23½ degrees south of the equator. The days are then longest at all places in the southern hemisphere, but at the shortest in the northern. This time of the year is termed the *winter solstice*.

From the tropic of Capricorn the sun appears to move forward, and to arrive at the equinoctial on the 20th of March.

Thus by a combination of the *annual* and diurnal motions of the earth, with the parallelism of its axis, and the obliquity of its orbit to the plane of its equator, the various seasons are produced, and the same quantity of light and darkness, in the space of a year, are distributed to every region of the globe.

The manner in which the sun enlightens the earth, the parallelism of its axis, and the increase and decrease of the days and nights, may be well illustrated by a small terrestrial globe, suspended by a string fastened to its north pole, as represented by the following figure.



A circle of wire *a b*, representing the plane of the earth's equator, may be held parallel to a table, and equal in height with the flame of a candle standing upon it. If the string be twisted a little towards the left hand, and the globe suspended within the circle, with its equator at the same height, the globe will begin to turn on its axis from west to east, and day and night will be represented by the light and shade produced by the candle on its surface. But if the globe be carried round the wire, to represent a year, the candle will illuminate both poles, and every spot on its surface will describe half a circle in the enlightened part, and half in the dark part, and make equality of day and night through the year. This is, however, not the case in nature, as has already been fully explained. If then the wire be inclined to the table at an angle of 23½ degrees, as represented by the circle *a b c d*, and the globe be carried gently round it, the seasons, and increase of day and

and night, will appear as they are in nature; i. e. when the globe is at *a*, the candle enlightens it no farther northward than the arctic circle *n o;* all within which, in the middle of our winter, is deprived of a sight of the sun; while all places within the antarctic, or opposite circle, have perpetual day: at this time the candle shines vertically on the tropic of Capricorn. As the earth moves towards *b* (the vernal equinox), if a small patch be laid on latitude $51\frac{1}{2}^{\circ}$ north, it will show how the days increase at London, and how the nights decrease. When it has arrived at *b*, the candle will then be perpendicularly over the equator, and, shining to both poles, equality of day and night will take place: as it proceeds towards *c* (the summer solstice), the days increase, and the candle shines more and more over the north pole: when it has arrived at *c*, the whole arctic circle, and the countries it includes, will revolve in continual sight of the sun; and all within the antarctic circle will be deprived of that sight. At this time the candle shines vertically on the tropic of Cancer. Moving from midsummer towards *d* (the autumnal equinox), the days will be found to decrease, and the nights to increase in length, till they come again to equality at *d*, and thence to the winter solstice, and so on.

The particular temperature which distinguishes each of the seasons, at any particular place, is owing to a difference in the sun's altitude, and the time of his continuance above the horizon of that place. In winter, the rays of the sun fall so obliquely, and the sun is such a short time above the horizon, that his influence in heating the earth is but very little, compared with what it is in summer. For at this season, the sun is so much higher than in winter, that his rays not only fall more perpendicularly, but more of them fall on any given space; and as the day is also much longer than the night, the temperature of the earth and the surrounding atmosphere must be much greater than in winter.

Since the power of the sun is greater in heating the earth at any particular place, when his rays fall most directly, and when the days are longest at that place, it may be asked, how does it happen that the heat is greatest about the end of July, when the sun is highest and the day longest about the 21st of June? The reason of this may easily be discovered, by attending a little to the manner in which bodies are heated. The heat which the earth receives is not transient, but is retained by it for some time. For, like other solid bodies, it receives heat and parts with it gradually. Now as the earth continues to receive more heat in the day than it gives out in the night, for a considerable time after the 21st of June, its temperature will continue to increase, till the days and nights begin to approach to an equality. But this is not the case till the end of July, at least; the earth goes on increasing in temperature, till about this time, when it is found to be much greater than about the 21st of June, although the sun be then higher at mid-day, and the day longer than at any other time of the year in the northern hemisphere.* The heat in July would be still greater were the sun at his mean distance from the earth; but this is not the case, for he is then at his greatest distance. However, the difference between his distance at this time and the mean distance being only $\frac{1}{64}$th part of the whole, it could not make a great alteration in the heating power of the rays. But if it does operate in any degree in diminishing the heat in the northern hemisphere in July, the same cause must operate in increasing the heat, but in a double degree, in the southern hemisphere in January. For the sun is $\frac{1}{64}$th part nearer the earth than his mean distance on the 1st of January. Consequently the heat must be greater in the southern hemisphere in January than in the northern in July, all other circumstances being the same. The effect of the direct influence of the sun are, however, greatly modified by the transportation of the temperature of one region into another, in consequence of that disturbance in the equilibrium of the atmosphere, which the action of the sun's rays necessarily produce.

Thus we see by what simple means the whole variety of the seasons are produced; and also how admirably fitted the means are to accomplish the end.

* The same phenomena take place in the southern hemisphere in a reverse order, or at six months' difference of time.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF JOHN SMEATON.

John Smeaton was born the 28th of May, 1724, O. S. at Austhorpe, near Leeds, in a house built by his grandfather, and where his family have resided ever since. The strength of his understanding, and the originality of his genius, appeared at an early age; his playthings were not the playthings of children, but the tools which men employ; and he appeared to have greater entertainment in seeing the men in the neighbourhood work, and asking them questions, than in any thing else. One day he was seen, to the distress of his family, on the top of his father's barn, fixing up something like a windmill. Another time he attended some men fixing a pump at a neighbouring village; and observing them cut off a piece of bored pipe, he was so lucky as to procure it, and he actually made with it a working pump that raised water. These anecdotes refer to circumstances that are said to have happened while he was in petticoats, and most likely before he attained his sixth year.

About his fourteenth and fifteenth year he had made for himself an engine for turning, and wrought several presents to his friends of boxes in ivory or wood, very neatly turned. He forged his iron and steel, and melted his metal; he had tools of every sort for working in wood, ivory, and metals. He had made a lathe, by which he had cut a perpetual screw in brass; a thing little known at that day, which was the invention of Mr. Henry Hindley, of York, with whom Mr. Smeaton soon became acquainted, and they spent many a night at Mr. Hindley's house till day-light, conversing on those subjects. Thus had Mr. Smeaton, by the strength of his genius and indefatigable industry, acquired, at the age of 18, an extensive set of tools, and the art of working in most of the mechanical trades, without the assistance of any master. A part of every day was generally occupied in forming some ingenious piece of mechanism.

Mr. Smeaton's father was an attorney, and desirous of bringing him up to the same profession. Mr. Smeaton therefore came up to London in 1742, and attended the courts in Westminster Hall; but finding, as his common expression was, that the law did not suit the bent of his genius, he wrote a strong memorial to his father on that subject; whose good sense from that moment left Mr. Smeaton to pursue the dictates of his genius in his own way.

In 1751 he began a course of experiments, to try a machine of his invention to measure a ship's way at sea, and also made two voyages, in company with Dr. Knight, to try it, and a compass of his own invention and making, which was made magnetical by Dr. Knight's artificial magnets. The second voyage was made in the Fortune sloop of war, commanded at that time by Captain Alexander Campbell.

In 1753 he was elected member of the Royal Society; the number of papers published in their Transactions will show the universality of his genius and knowledge.

In 1759 he was honoured by an unanimous vote with their gold medal, for his paper intitled, "An Experimental Inquiry concerning the Natural Powers of Water and Wind to turn Mills, and other Machines, depending on a circular Motion." This paper, he says, was the result of experiments made on working models in the year 1752 and 1753, but not communicated to the Society till 1759; before which time he had an opportunity of putting the effect of these experiments into real practice, in a variety of cases, and for various purposes, so as to assure the Society he had found them to answer.

In December, 1755, the Eddystone Lighthouse was burnt down. Mr. Weston, the chief proprietor, and the others, being desirous of rebuilding it in the most substantial manner, inquired of the Earl of Macclesfield, then President of the Royal Society, whom he thought the most proper to rebuild it; his Lordship recommended Mr. Smeaton. Mr. Smeaton undertook the work, and completed it in the summer of 1759. Of this Mr. Smeaton gives an ample description in the volume he published in 1791.

Though Mr. Smeaton completed the building of the Eddystone Lighthouse in 1759, a work that does him so much credit, yet it appears he did not soon get into full business as a civil engineer; for in 1764, while in Yorkshire, he offered himself a candidate for one of the receivers of the Derwentwater estate; and on the 31st of December in that year, he was appointed, at a full board of Greenwich Hospital, in a manner highly flattering to himself, when two other persons strongly recommended and powerfully supported were candidates for the employment. In this appointment he was very happy, by the assistance and abilities of his partner, Mr. Walton, one of the receivers; who, taking upon himself the management and accounts, left Mr. Smeaton leisure and opportunity to exert his abilities on public works, as well as to make any improvements in the mills and in the estates of Greenwich Hospital. By the year 1775, he had so much business as a civil engineer, that he wished to resign this appointment, and would have done it then, had not his friends, the late Mr. Stuart, the hospital surveyor, and Mr. Ibbetson, their secretary, prevailed upon him to continue in the office about two years longer.

Mr. Smeaton having now got into full business as a civil engineer, performed many works of general utility. He made the river Calder navigable; a work that required great skill and judgment, owing to the very impetuous floods in that river. He planned and attended the execution of the great canal in Scotland, for conveying the trade of the country either to the Atlantic or German Ocean; and having brought it to the place originally intended, he declined a handsome yearly salary, in order that he might attend to the multiplicity of his other business.

On the opening of the great arch at London bridge, the excavation around and under the starlings was so considerable, that the bridge was thought to be in great danger of falling. He was then in Yorkshire, and was sent for by express, and arrived with the utmost dispatch. "I think," says Mr. Holmes, the author of his Life, "it was on a Saturday morning, when the apprehension of the bridge was so general, that few would pass over or under it. He applied himself immediately to examine it, and to sound about the starlings as minutely as he could; and the committee being called together, adopted his advice, which was to re-purchase the stones that had been taken from the middle pier, then lying in Moorfields, and to throw them into the river to guard the starlings."—Nothing shows the apprehensions concerning the falling of the bridge more than the alacrity with which this advice was pursued; the stones were re-purchased that day, horses, carts, and barges, were got ready, and they began the work on Sunday morning. Thus Mr. Smeaton, in all human probability, saved London bridge from falling, and secured it till more effectual methods could be taken.

The vast variety of mills which Mr. Smeaton constructed, so greatly to the satisfaction and advantage of the owners, will show the great use which he made of his experiments in 1752 and 1753; for he never trusted to theory in any case where he could have an opportunity to investigate it by experiment. He built a steam-engine at Austhorpe, and made experiments thereon, purposely to ascertain the power of Newcomen's steam-engine, which he improved, and brought to a far greater degree of perfection, both in its construction and powers, than it was before.

Mr. Smeaton, during many years of his life, was a frequent attendant on parliament, his opinion being continually called for. And here his strength of judgment and perspicuity of expression had its full display. It was his constant custom, when applied to plan or support any measure, to make himself fully acquainted with it, to see its merits, before he would engage in it. By this caution, added to the clearness of his description and the integrity of his heart, he seldom failed to obtain for the bill which he supported an act of parliament. No one was heard with more attention, nor had any one ever more confidence placed in his testimony. In the courts of law he had several compliments paid him from the bench by Lord Mansfield and others, for the new light which he threw on difficult subjects.

About the year 1785, Mr. Smeaton's health began to decline; and he then took the resolution to endeavour to avoid all the business he could, so that he might have leisure to publish an account of his inventions and works, which was certainly the first wish of his heart; for he has often been heard to say, that "he thought he could not render so much service to his country as by doing that." He got only his account of the Eddystone Lighthouse completed, and some preparations to his intended Treatise on Mills; for he could not resist the solicitations of his friends in various works; and Mr. Aubert, whom he greatly loved and respected, being chosen chairman of Ramsgate harbour, prevailed upon him to accept the place of engineer to that harbour; and to their joint efforts the public is chiefly indebted for the improvements that have been made there within the last 30 years; which fully appears in a report that Mr. Smeaton gave in to the Board of Trustees in 1791, which they immediately published.

Mr. Smeaton being at Austhorpe, walking in his garden, on the 16th of September, 1792, was struck with the palsy, and died the 28th of October. "In his illness," says Mr. Holmes, "I had several letters from him, signed with his name, but written and signed by another's pen; the diction of them shewed that the strength of his mind had not left him. In one written the 26th of September, after minutely describing his health and feelings, he says, 'In consequence of the foregoing, I conclude myself nine-tenths dead; and the greatest favour the Almighty can do me, as I think, will be to complete the other part; but as it is likely to be a lingering illness, it is only in his power to say when that is likely to happen.'"

Mr. Smeaton had a warmth of expression that might appear to those who did not know him well to border on harshness; but those more intimately acquainted with him knew that it arose from the intense application of his mind, which was always in the pursuit of truth, or engaged in investigating difficult subjects. He would sometimes break out hastily, when any thing was said that did not tally with his ideas; and he would not give up any thing he argued for, till his mind was convinced by sound reasoning. In all the social duties of life he was exemplary; he was a most affectionate husband, a good father, a warm, zealous, and sincere friend, always ready to assist those he respected, and often before it was pointed out to him in what way he could serve them. He was a lover and encourager of merit wherever he found it; and many men are, in a great measure, indebted to his assistance and advice for their present situations. As a companion, he was always entertaining and instructive; and none could spend any time in his presence without improvement.

As a civil engineer, he was perhaps unrivalled, certainly not excelled by any one, either of the present or former times. His building the Eddystone Lighthouse, were there no other monument of his fame, would establish his character. The Eddystone rocks have obtained their name from the great variety of contrary sets of the tide or current in their vicinity. They are situated nearly S.S.W. from the middle of Plymouth Sound; their distance from the port of Plymouth is about 14 miles. They are almost in the line which joins the Start and the Lizard Points; and as they lie nearly in the direction of vessels coasting up and down the Channel, they were unavoidably, before the establishment of a Lighthouse there, very dangerous, and often fatal to ships. Their situation with regard to the Bay of Biscay and the Atlantic is such, that they lie open to the swells of the bay and ocean, from all the south-western points of the compass; so that all the heavy seas from the south-west quarter come uncontrolled upon the Eddystone rocks, and break upon them with the utmost fury. Sometimes, when the sea is to all appearance smooth and even, and its surface unruffled by the slightest breeze, the ground swell, meeting the slope of the rocks, the sea beats upon them in a frightful manner, so as not only to obstruct any work being done on the rock, or even landing upon it, when, figuratively speaking, you might go to sea in a walnut-shell. That circumstances fraught with danger surrounding it should excite mariners to wish for a Lighthouse, is not wonderful; but the danger attending the erection leads us to wonder that any one could be found hardy enough to undertake it. Such a man was first found in the person of Mr. H. Winstanley, who, in the year 1696, was furnished by the Trinity House with the necessary powers. In 1700 it was finished; but in the great storm of November, 1703, it was destroyed, and the projector perished in the ruins. In 1709, another, upon a different construction, was erected by a Mr. Rudyerd, which, in 1755, was unfortunately consumed by fire. The next building was, as we have seen, under the direction of Mr. Smeaton; who, having considered the errors of the former constructions, has judiciously guarded against them, and erected a building, the demolition of which seems little to be dreaded, unless the rock on which it is erected should perish with it. Of his works, in constructing bridges, harbours, mills, engines, &c. &c. it were endless to speak. Of his inventions and improvements of philosophical instruments, as the air-pump, the pyrometer, hygrometer, &c. &c. some idea may be formed from the list of his writings. See Hutton's Dict.

SOLUTIONS OF QUESTIONS.

Quest. 62, *answered by* J. D. *(the Proposer).*

Here 10 acres would have fed 15 oxen for 10 weeks, or 30 acres 18 oxen for 25 weeks, if the grass had not grown after the first 5 weeks; for

A. A. Ox.
3 : 10 :: 9
W. W.
10 : 5

$$\left.\begin{matrix} 3 : 10 :: 9 \\ 10 : 5 \end{matrix}\right\} \frac{10 \times 9 \times 5}{10 \times 3} = 15 \text{ oxen.}$$

A. A. Ox.
3 : 30 :: 9
W. W.
25 : 5

$$\left.\begin{matrix} 3 : 30 :: 9 \\ 25 : 5 \end{matrix}\right\} \frac{30 \times 9 \times 5}{3 \times 25} = 18 \text{ oxen.}$$

But, as 10 acres fed 20 oxen for 10 weeks, 20—15 = 5 oxen must have been fed for 10 weeks, by the grass which grew on these 10 acres during the second 5 weeks. Now, at the same rate of growth, 24 oxen may be fed for 25 weeks, by the grass which will grow on 30 acres during the 20 weeks, which remain after the first 5 weeks; for

W. W. Ox.
25 : 10 :: 5
W. W.
5 : 20
A. A.
10 : 30

$$\left.\begin{matrix} 25 : 10 :: 5 \\ 5 : 20 \\ 10 : 30 \end{matrix}\right\} \frac{10 \times 20 \times 30 \times 5}{10 \times 5 \times 25} = 24 \text{ oxen.}$$

Thus, the grass which grows during the last 20 weeks, will feed -	24 oxen.
and that which was on the field at the beginning of the 25 weeks, together with its growth during the first five weeks, will feed - -	18 oxen.
Sum	42 oxen, *Ans.*

We received several solutions of this intricate question; but none of them was correct, except Mr. Harding's. Ed.

QUESTION FOR SOLUTION.

Quest. 65, *proposed by* Master Thomas Morris, *Liverpool.*

A reservoir for water has two cocks to supply it: by the first alone it may be filled in 40 minutes, by the second in 50 minutes: and it has also two discharging cocks; the first will empty three such reservoirs in 100 minutes, and the latter two such in 180 minutes. Now supposing these four cocks are all left open, and the water comes in, in what time will the cistern be filled, supposing the influx and efflux of the water to be always the same?

We insert the above question, as we are assured the Proposer is only 10 years of age. We are sorry that his solution of the 61st question came too late for insertion.

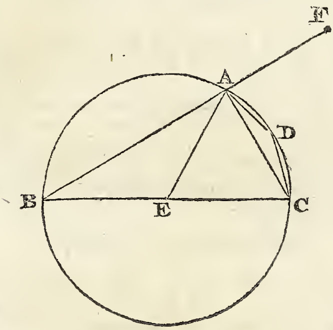
GEOMETRY.

PROPOSITION XXXI.

THEOREM.—*In a circle, the angle in a semicirle is a right angle; but the angle in a segment greater than a semicircle is less than a right angle: and the angle in a segment less than a semicircle is greater than a right angle.*

Let A B C D be a circle, of which the diameter is B C, and centre E; and draw C A, dividing the circle into the segments A B C, A D C, and join B A, A D, D C; the angle in the semicircle B A C is a right angle; and the angle in the segment A B C, which is greater than a semicircle, is less than a right angle; and the angle in the segment A D C, which is less than a semicircle, is greater than a right angle.

Join A E, and produce B A to F; and because B E is equal to E A, the angle E A B is equal to E B A; also, because A E is equal to E C, the angle E A C is



equal to E C A; wherefore the whole angle B A C is equal to the two angles A B C, A C B: But F A C, the exterior angle of the triangle A B C, is equal to the two angles A B C, A C B; therefore the angle B A C is equal to the angle F A C, and each of them is therefore a right angle: Wherefore the angle B A C in a semicircle is a right angle.

And because the two angles A B C, B A C of the triangle A B C are together less than two right angles, and that B A C is a right angle, A B C must be less than a right angle; and therefore the angle in a segment A B C greater than a semicircle, is less than a right angle.

And because A B C D is a quadrilateral figure in a circle, any two of its opposite angles are equal to two right angles; therefore the angles A B C, A D C are equal to two right angles; and A B C is less than a right angle; wherefore the other A D C is greater than a right angle.

Besides, it is manifest, that the circumference of the greater segment A B C falls without the right angle C A B; but the circumference of the less segment A D C falls within the right angle C A F. And this is all that is meant, when in the Greek text, and the translations from it, the angle of the greater segment is said to be greater, and the angle of the less segment is said to be less, than a right angle.

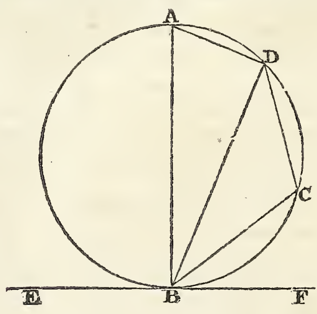
COR. From this it is manifest, that if one angle of a triangle be equal to the other two, it is a right angle, because the angle adjacent to it is equal to the same two; and when the adjacent angles are equal, they are right angles.

PROPOSITION XXXII.

THEOREM.—*If a straight line touches a circle, and from the point of contact a straight line be drawn cutting the circle, the angles made by this line with the line touching the circle, shall be equal to the angles which are in the alternate segments of the circle.*

Let the straight line E F touch the circle A B C D in B, and from the point B let the straight line B D be drawn, cutting the circle: The angles which B D makes with the touching line E F, shall be equal to the angles in the alternate segments of the circle: that is, the angle F B D is equal to the angle which is in the segment D A B, and the angle D B E to the angle in the segment B C D.

From the point B draw B A at right angles to E F, and take any point C in the circumference B D, and join A D, D C, C B; and because the straight line E F touches the circle A B C D in the point B, and B A is drawn at right angles to the



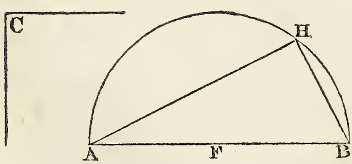
touching line from the point of contact B, the centre of the circle is in B A; therefore the angle A D B in a semicircle is a right angle, and consequently the other two angles B A D, A B D are equal to a right angle: But A B F is likewise a right angle; therefore the angle A B F is equal to the angles B A D, A B D: Take from these equals the common angle A B D; therefore the remaining angle D B F is equal to the angle B A D, which is in the alternate segment of the circle; and because A B C D is a quadrilateral figure in a circle, the opposite angles B A D, B C D are equal to two right angles; therefore the angles D B F, D B E, being likewise equal to right angles, are equal to the angles B A D, B C D; and D B F has been proved equal to B A D: Therefore the remaining angle D B E is equal to the angle B C D in the alternate segment of the circle. Wherefore, if a straight line, &c. Q. E. D.

PROPOSITION XXXIII.

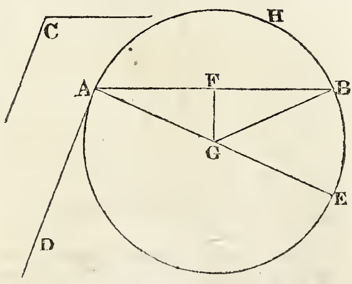
Problem.—*Upon a given straight line to describe a segment of a circle, containing an angle equal to a given rectilineal angle.*

Let A B be the given straight line, and the angle at C the given rectilineal angle; it is required to describe upon the given straight line A B a segment of a circle, containing an angle equal to the angle C.

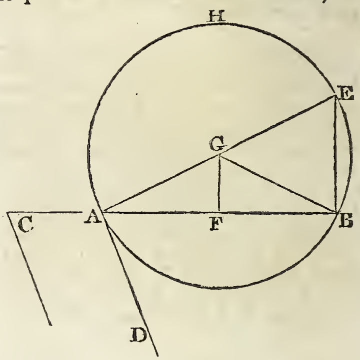
First, let the angle at C be a right angle, and bisect A B in F, and from the centre F, at the distance F B, describe the semicircle A H B; therefore the angle A H B in a semicircle is equal to the right angle at C.



But, if the angle C be not a right angle, at the point A, in the straight line A B, make the angle B A D equal to the angle C, and from the point A draw A E at



right angles to A D; bisect A B in F, and from F draw F G at right angles to A B, and join G B: And because A F is equal to F B, and F G common to the triangles A F G, B F G, the two sides A F, F G are equal to the two B F, F G; and the angle A F G is equal to the angle B F G; therefore the base A G is equal to the base G B: and the circle described from the centre G, at the distance G A, shall pass through the point B; let this be the circle A H B: And because from the point A the extremity of the diameter A E, A D is drawn at right angles to A E, therefore A D touches the circle; and because A B drawn from the point of contact A cuts the circle, the



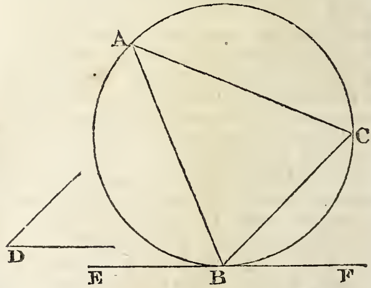
angle D A B is equal to the angle in the alternate segment A H B: But the angle D A B is equal to the angle C, therefore also the angle C is equal to the angle in the segment A H B: Wherefore, upon the given straight line A B the segment A H B of a circle is described, which contains an angle equal to the given angle at C. Which was to be done.

PROPOSITION XXXIV.

Problem.—*To cut off a segment from a given circle, which shall contain an angle equal to a given rectilineal angle.*

Let A B C be the given circle, and D the given rectilineal angle; it is required to cut off a segment from the circle A B C, that shall contain an angle equal to the given angle D.

Draw the straight line E F touching the circle A B C in the point B, and at the

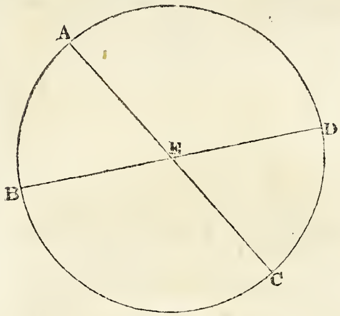


point B, in the straight line B F, make the angle F B C equal to the angle D: Therefore, because the straight line E F touches the circle A B C, and B C is drawn from the point of contact B, the angle F B C is equal to the angle in the alternate segment B A C of the circle: But the angle F B C is equal to the angle D; therefore the angle in the segment B A C is equal to the angle D: Wherefore the segment B A C is cut off from the given circle A B C, containing an angle equal to the given angle D. Which was to be done.

PROPOSITION XXXV.

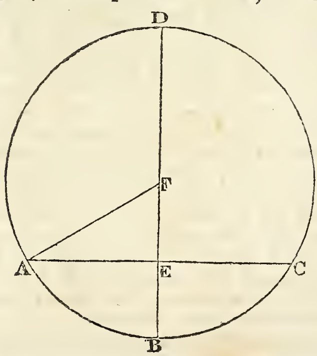
Theorem.—*If two straight lines within a circle cut one another, the rectangle contained by the segments of one of them, is equal to the rectangle contained by the segments of the other.*

Let the two straight lines A C, B D, within the circle A B C D, cut one another in the point E: the rectangle contained by A E, E C is equal to the rectangle contained by B E, E D



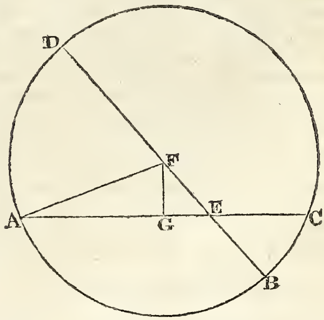
If A C, B D pass each of them through the centre, so that E is the centre; it is evident, that A E, E C, B E, E D, being all equal, the rectangle A E, E C, is likewise equal to the rectangle B E, E D.

But let one of them B D pass through the centre, and cut the other A C which does not pass through the centre, at right angles, in the point E: Then, if B D be



bisected in F, F is the centre of the circle A B C D; join A F: And because B D, which passes through the centre, cuts the straight line A C, which does not pass through the centre, at right angles in E, A E, E C are equal to one another: And because the straight line B D is cut into two equal parts in the point F, and into two unequal in the point E, the rectangle B E, E D, together with the square of E F, is equal to the square of F B: that is, to the square of F A; but the squares of A E, E F are equal to the square of F A; therefore the rectangle B E, E D, together with the square of E F, is equal to the squares of A E, E F: Take away the common square of E F, and the remaining rectangle B E, E D is equal to the remaining square of A E; that is, to the rectangle A E, E C.

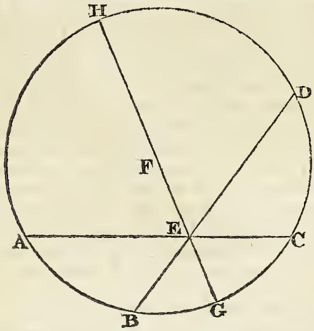
Next, let B D, which passes through the centre, cut the other A C, which does not pass through the centre, in E, but not at right angles: Then, as before, if B D be bisected in F, F is the centre of the circle. Join A F, and from F draw F G perpendicular to A C; therefore A G is equal to G C; wherefore the rectangle A E, E C, together with the square of E G, is equal to the square of A G: To each of these equals add the square of G F: therefore



the rectangle A E, E C, together with the squares of E G, G F, is equal to the squares of A G, G F: But the squares of E G, G F are equal to the square of E F; and the squares of A G, G F are equal to the square of A F: Therefore the rectangle A E, E C, together with the square of E F, is equal to the square of A F; that is, to the square of F B: But the square of F B is equal to the rectangle B E, E D, together with the square of E F; therefore the rectangle A E, E C, together with the square of E F, is equal to the rectangle B E, E D, together with the square of E F. Take away the common square of E F, and the remaining rectangle A E, E C, is therefore equal to the remaining rectangle B E, E D.

Lastly, let neither of the straight lines

A C, B D pass through the centre: Take



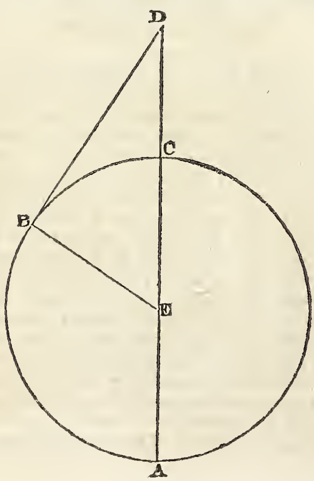
the centre F, and through E, the intersection of the straight lines A C, D B, draw the diameter G E F H: And because the rectangle A E, E C is equal, as has been shewn, to the rectangle G E, E H; and, for the same reason, the rectangle BE, E D is equal to the same rectangle G E, E H; therefore the rectangle A E, E C is equal to the rectangle B E, E D. Wherefore, if two straight lines, &c. Q. E. D.

PROPOSITION XXXVI.

Theorem.—*If from any point without a circle two straight lines be drawn, one of which cuts the circle, and the other touches it; the rectangle contained by the whole line which cuts the circle, and the part of it without the circle, shall be equal to the square of the line which touches it.*

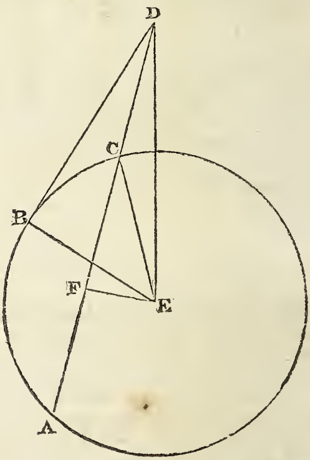
Let D be any point without the circle A B C, and D C A, D B two straight lines drawn from it, of which D C A cuts the circle, and D B touches the same: The rectangle A D, D C is equal to the square of D B.

Either D C A passes through the centre,



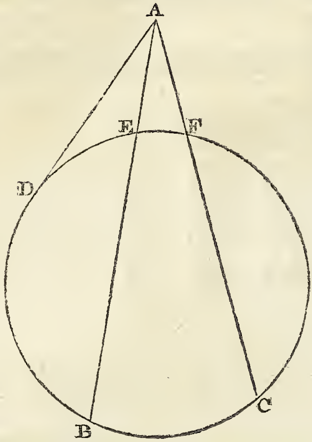
or it does not: first, let it pass through the centre E, and join E B; therefore the angle E B D is a right angle: And because the straight line A C is bisected in E, and produced to the point D, the rectangle A D, D C, together with the square of E C, is equal to the square of E D, and C E is equal to E B. Therefore the rectangle A D, D C, together with the square of E B, is equal to the square of E D: But the square of E D is equal to the squares of E B, B D, because E B D is a right angle: Therefore the rectangle A D, D C, together with the square of E B, is equal to the squares of E B, B D: Take away the common square of E B; therefore the remaining rectangle A D, D C is equal to the square of the tangent D B.

But if D C A does not pass through the centre of the circle A B C, take the centre E, and draw E F perpendicular to A C, and join E B, E C, E D: And because the straight line E F, which passes through the centre, cuts the straight line A C, which does not pass through the centre,



at right angles, it shall likewise bisect it; therefore A F is equal to F C: And because the straight line A C is bisected in F, and produced to D, the rectangle A D, D C, together with the square of FC, is equal to the square of F D: To each of these equals add the square of F E; therefore the rectangle A D, D C, together with the squares of C F, F E, is equal to the squares of D F, F E: But the square of E D is equal to the squares of D F, F E, because E F D is a right angle: and the square of E C is equal to the squares of C F, F E; therefore the rectangle A D, D C, together with the square of E C, is equal to the square of E D: And C E is equal to E B; therefore the rectangle AD, D C, together with the square of E B, is equal to the square of E D: But the squares of E B, B D are equal to the square of E D, because E B D is a right angle; therefore the rectangle A D, D C, together with the square of E B, is equal to the squares of E B, B D: Take away the common square of E B; therefore the remaining rectangle, A D, D C is equal to the square of D B. Wherefore, if from any point, &c. Q. E. D.

Cor. If from any point without a circle, there be drawn two straight lines cutting it, as A B, A C, the rectangles contained by the whole lines and the parts of them



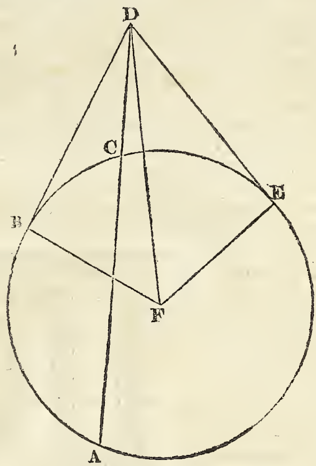
without the circle, are equal to one another; viz. the rectangle B A, A E to the rectangle C A, A F: For each of them is equal to the square of the straight line A D which touches the circle.

PROPOSITION XXXVII.

Theorem.—*If from a point without a circle there be drawn two straight lines, one of which cuts the circle, and the other meets it; if the rectangle contained by the whole line which cuts the circle, and the part of it without the circle be equal to the square of the line which meets it, the line which meets shall touch the circle.*

Let any point D be taken without the circle A B C, and from it let two straight lines D C A and D B be drawn, of which D C A cuts the circle, and D B meets it; if the rectangle A D, D C be equal to the square of D B; D B touches the circle.

Draw the straight line D E, touching the circle A B C, find its centre F, and join F E, F B, F D; then F E D is a right angle: And because D E touches the circle A B C, and D C A cuts it, the rectangle A D, D C is equal to the square of D E: But the rectangle A D, D C is, by hypothesis, equal to the square of D B: Therefore the square of D E is equal to the square of D B; and the straight line D E equal to the straight line D B, And F E is equal to F B, wherefore D E, E F are equal to D B, B F; and the base F D is common to the



two triangles D E F, D B F; therefore the angle D E F is equal to the angle D B F; but D E F is a right angle, therefore also D B F is a right angle: And F B, if produced, is a diameter, and the straight line which is drawn at right angles to a diameter, from the extremity of it, touches the circle: Therefore D B touches the circle A B C. Wherefore, if from a point, &c. Q. E, D.

MECHANICS.

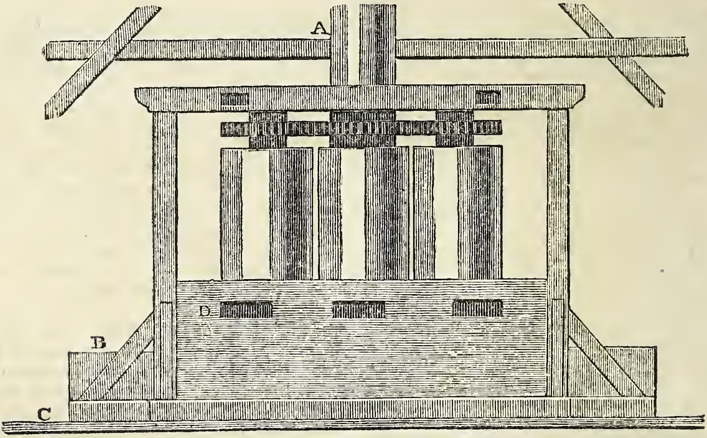
OF MILLS.

Machines, by which the larger masses of matter are crushed, broken, or ground, are generally comprehended under the name of mills. After the pestle and mortar, the simplest machine of this kind appears to be the stamping mill; the stampers resemble the hammers of the mill employed in the extraction of oils from seeds, and the machine is used for reducing to powder the ores of metals, and sometimes also barks and linseed; the surface of the stampers being armed with iron or steel. But barks and seeds are more usually ground by the repeated pressure of two wheels of stone, rolling on an axis, which is forced in a horizontal direction round a fixed point.

The materials for making gunpowder, are also ground by a wheel revolving in a trough: in order to corn them, they are moistened, and put into boxes with a number of holes in their bottoms, and these boxes being placed side by side, in a circular frame, suspended by cords, the frame is agitated by a crank revolving horizontally, and the paste shaken through the holes: the corns are polished, by causing them to revolve rapidly within a barrel.

The rollers by which sugar canes are pressed, are in general situated vertically, the middle one of these being turned by horses, by mules, or by water, and the canes being made to turn round it, so as to pass through both interstices in succession. It appears to be of some advantage in presses of this kind, that all the rollers should be turned, independently of their action, on the materials interposed, since the friction of two rollers may tend to draw the materials into the space between them, with more regularity and greater force, than the action of a single roller would do. For this reason, it may be advisable to retain the toothed wheels turning the rollers, even when their axis are not firmly fixed, but held together by an elastic hoop.

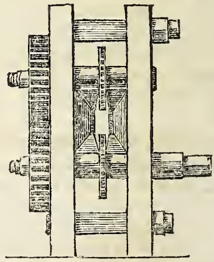
In the following figure the axis A is turned either by animal force or by water.



The liquor is collected in the trough B, and runs off in the channel C. The openings D are for the purpose of adjusting the axis of the rollers. The canes are supplied by the hands of the workmen.

Substances are seldom extended or flattened by forces that tend immediately to increase the dimensions of the substance only: this is generally performed by reducing the magnitude of the substance in another direction, sometimes by means of pressure, but more effectually by percussion. The rollers of the press employed for laminating metals are turned by machinery, and are capable of being moved backwards and forwards, in order to repeat the operation on the same substance; their distance is adjusted by screws, which are turned at once by pinions fixed on the same axis, in order that they may be always parallel. In this manner lead, copper, and silver, are rolled into plates; and a thin plate of silver being soldered to a thicker one of copper, the compound plate is submitted again to the action of the press, and made so thin as to be afforded at a moderate expense. The glazier's vice is a machine of the same nature, for forming window lead: the softness of the lead enables it to assume the required shape, in consequence of the pressure of the rollers or wheels; and the circumference of these wheels is indented, in order to draw the lead along by the corresponding elevations.

The following figure represents a machine of this kind:



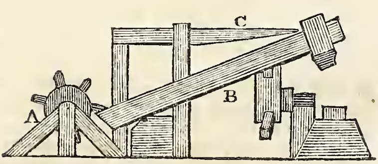
The vacuity in the middle shows the form of the section of the lead, which is drawn through it.

In drawing wire, the force is originally applied in the direction of the extension; but it produces a much stronger lateral compression, by means of the conical apertures through which the wire is successively drawn. For holding the large wire, pincers are at first used, which embrace it strongly while they pull, and open when they advance to a new position, the interruption being perhaps of use, by enabling the pincers to acquire a certain momentum before they begin to extend the wire; but afterwards, when the wire is finer, it is simply drawn through the aperture from one wheel or drum to another. During the operation, it requires frequent annealing, which causes a scale to form on its surface; and this must be removed by rolling it in a barrel with proper materials; for the application of an acid is said to injure the temper of the metal. Copper is sometimes drawn into wire so large, as to serve for the bolts used in shipbuilding, especially for sheathing ships' bottoms. Silver wire thinly covered with gold, is rendered extremely fine, and then flattened, in order to be fit for making gold thread: the thickness of the gold is inconceivably small, much less than the millionth part of an inch, and sometimes only a ten millionth part.

The operation of coining depends also in a great degree on an extension of the metal, for the bars are taken out of the moulds, and scraped, brushed, flattened in a mill, and brought to the proper thickness of the pieces to be coined; the plates thus reduced are then cut into a round form, called blanks or planchets, with an instrument fastened to the lower end of an arbor, whose upper end is formed into a screw, which being turned by an iron handle turns the arbor, and lets the steel, well sharpened in form of a punch cutter, fall on the plates; and thus a piece is punched out.

In forges the hammers are raised by machinery, and thrown forcibly against a spring, so as to recoil with great velocity. With the help of this spring the hammer sometimes makes 500 strokes in a minute, its force being many times greater than the weight of the hammer. Such forges are used in making malleable iron, in forming copper plates, and in manufacturing steel.

The following figure represents a hammer of this kind elevatad by the plugs, projecting from an axis, either at A, or



more conveniently at B, and thrown forcibly against the wooden spring C.

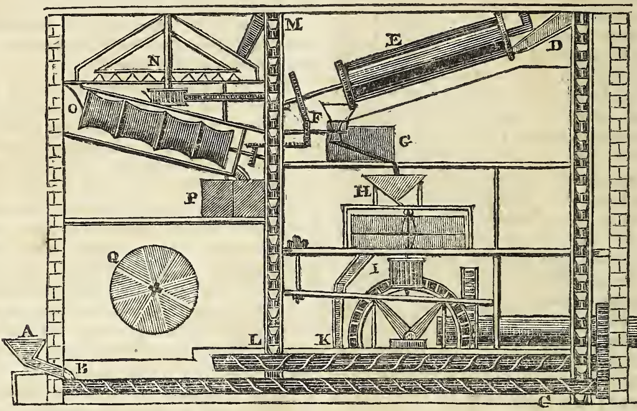
OF CORN MILLS.

Some kinds of grain are occasionally ground in mills of iron or steel, which consist of a solid cylinder or cone turning with a hollow one, both the surfaces being cut obliquely into teeth.

The common mill for grinding corn is composed of two circular stones of silicious grit, placed horizontally; the upper one revolves with considerable velocity, and is supported by an axis passing through the lower one, at a distance variable at pleasure. When the diameter is five feet, the stone usually makes about 90 revolutions in a minute; if the velocity were greater, the flour would be too much heated. The corn is shaken out of a funnel or hopper, by means of projections from the revolving axis, which strikes against the orifice; it passes through the middle of the upper mill-stone, and is readily admitted between the stones; the lower stone is slightly convex, and the upper one somewhat more concave, so that the corn passes over more than half the radius of the stone before it begins to be ground: after being reduced to powder, it is discharged at the circumference, its escape being favoured by the convexity of the lower stone, as well as by the centrifugal force. The surface of the stones is cut into grooves, in order to make them act more readily and effectually on the corn. The resistance in grinding wheat has been estimated at about a thirty-fifth of the weight of the mill-stone. The stones have sometimes been placed vertically, and the axis supported upon friction wheels: but the common position appears to be more eligible for mills on a large scale. It is said that a man and a boy may grind by a hand mill a bushel of wheat in an hour; in a water mill, the grinding and dressing of a bushel of wheat, is equivalent to the effect of 20160 pounds of water falling through a height of 10 feet, which is about as much as the work of a labourer, for little more than half an hour. In a wind-mill, when the velocity is increased by the irregular action of the wind, the corn is sometimes forced rapidly through the mill without being sufficiently ground. There is an elegant method of preventing this by means of the centrifugal force of two balls, which fly out as soon as the velocity is augmented; and as they rise in the arc of a circle, allow the end of a lever to rise with them, while the opposite end of the lever descends with the upper mill-stone, and brings it a little nearer to the lower one.* The bran or

* See page 226, vol. i.

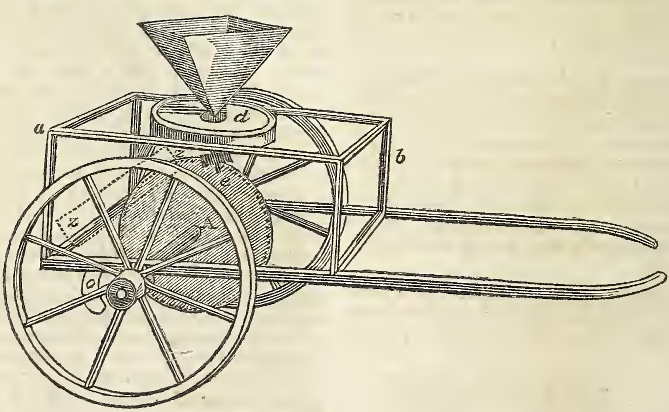
husk is seperated from the flour, by sifting it in the bolting mill, which consists of a cylindrical sieve, placed in an inclined position, and turned by machinery, as represented by the letter E in the following figure, which exhibits a corn mill, with some of the improvements made in America by Mr. Ellicott and Mr. Evans.



The corn, being poured into the funnel A, is conveyed by the revolutions of a spiral B C to C, whence it is raised by the chain of buckets to C D, to be cleaned by the revolving sieve E and the fan F; it is then deposited in the granary G, which supplies the funnel or mill hopper H; this being perpetually agitated by the iron axis of the upper mill-stone, shakes it by degrees into the perforation of the stone; it escapes, when ground, at I, and is conveyed by means of the carrier K L, and the elevator L M, to the cooler N, where it is spread on a large surface: it passes afterwards to the bolter O, and is received into the binn P from whence it is taken, to be packed in sacks or barrels. Q represents the surface of a mill-stone cut into furrows, in order to make it act more readily on the corn.

A TRAVELLING CORN-MILL.

The following figure represents a mill, which depends on the draught of a horse and the friction of the road for its motion. It is meant to move round a green, or any smooth road, and to travel from one house or village to another.



a b is a square frame of scantling, fixed on the shafts of a common cart: in this frame is fixed the case *c*, which contains the iron mill-stones *d*; the upper stone, as usual, turned and supported by the trundle or pinion *e* (the support of which, and its regulator, cannot be represented in the drawing, but are the same as in a common mill). The iron part of the spindle that is fixed into the stone is supported on three or four friction-wheels, to keep the stone steady when any inequalities are in the road; and which can, by screws, raise or depress the stone according to the fineness of the flour required, or the grain to be ground. A cog-wheel, A, is fixed on a square part of the axle of the cart-wheels, and is about a foot less in diameter. This cog-wheel can be easily separated from the trundle *e*, when the mill travels from one place to another. Inclining under the stones is the bolting sieve *z z*, represented by dotted lines, with teeth that act in the trundle *e*. The flour is ejected from the stones into this circulating sieve, and falls through it into a close case that deposits it in the bag *o*; while the bran flowing through the length of the sieve, is received in another bag. The stones should be about three feet in diameter (if of cast iron, so much the better), and the whole machine covered. It is conceived, one horse will draw the mill and a miller, and grind a bushel of wheat in travelling about one mile and a half.

ELECTRICITY.

OF ATMOSPHERICAL ELECTRICITY.

Air is one of those bodies which have received the name of *electrics*, because they are capable of being positively or negatively charged with electric matter. It not only contains that portion of electricity which seems necessary to the constitution of all terrestrial bodies, but it is liable also to be charged negatively or positively when electricity is abstracted or introduced by means of conducting bodies. These different states must occasion a variety of phenomena, and in all probability contribute very considerably to the various combinations and decompositions which are continually going on in the air. The electrical state of the atmosphere, then, is a point of considerable importance, and has with great propriety occupied the attention of philosophers ever since Dr. Franklin demonstrated that thunder is occasioned by the agency of electricity.

The most complete set of observations on the electricity of the atmosphere were made by Professor Beccaria of Turin. He found the air almost always positively electrical, especially in the day-time and in dry weather. When dark or wet weather clears up, the electricity is always negative. Low thick fogs rising into dry air carry up a great deal of electric matter.

In the morning, when the hygrometer indicates dryness equal to that of the preceding day, positive electricity obtains even before sunrise. As the sun gets up, this electricity increases more remarkably if the dryness increases. It diminishes in the evening.

The mid-day electricity of days equally dry is proportional to the heat.

Winds always lessen the electricity of a clear day, especially if damp.

For the most part, when there is a clear sky and little wind, a considerable electricity arises after sunset at dew falling.

Considerable light has lately been thrown upon the sources of atmospherical electricity by the experiments of Saussure, Humboldt, and other philosophers. Air is not only electrified by friction like other electric bodies, but the state of its electricity is changed by various chemical operations which often go on in the atmosphere. Evaporation seems in all cases to convey electric matter into the atmosphere; and Saussure has ascertained that the quantity of electricity is much increased when water is decomposed, as when water is dropt on a red hot iron. On the other hand, when steam is condensed into vesicular vapour, or into water, the air becomes negatively electric. Hence it would seem that electricity enters as a component part into water; that it separates when water is decomposed or expanded into steam, and is re-united when the steam is condensed again into water.

Mr. Canton has ascertained that dry air, when heated, becomes negatively electric, and positive when cooled, even when it is not permitted to expand or contract: and the expansion and contraction of air also occasions changes in its electric state.

Thus there appears to be at least four sources of atmospheric electricity known; namely, Friction; Evaporation; Heat and cold; Expansion and Contraction: not to mention the electricity evolved by the melting, freezing, solution, &c. of various bodies in contact with air.

As air is an electric, the matter of electricity, when accumulated in any particular strata, will not immediately make its way to the neighbouring strata, but will induce in them changes similar to what is induced upon plates of glass or similar bodies piled upon each other, Therefore if a stratum of air be electrified positively, the stratum immediately above it will be negative, the stratum above that positive, and so on. Suppose now that an imperfect conductor were to come into contact with each of these strata, we know, from the principles of electricity, that the equilibrium would be restored, and that this would be attended with a loud noise, and with a flash of light. Clouds which consist of vesicular vapours mixed with particles of air are imperfect conductors; if a cloud therefore come into contact with two such strata, a thunder-clap would follow. If a positive stratum be situated near the earth, the intervention of a cloud will serve to bring the stratum within the striking distance, and a thunder-clap will be heard while the electrical fluid is discharging itself into the earth. If the stratum be negative, the contrary effects will take place.

It has been proved by Mr. Canton that dry air, when heated, becomes negatively electrified, but that it assumes the positive state when cooled. He has also shewn that it undergoes changes in its electrical condition as it is exposed to various degrees of pressure; and Beccaria, Cavallo, Achard, and other experimental enquirers, have ascertained that these changes are connected with meteorological phenomena.

On this subject we quote the following observations from Humboldt, which that illustrious traveller made in the valleys of Aragua: "Being sufficiently habituated to the climate," says he, "not to fear the effects of tropical rains, we remained on the shore to observe the electrometer. I held it more than twenty minutes in my hand, six feet above the ground, and observed that, in general, the pith balls separated only a few seconds before the lightning was seen. The separation was four lines. The electric discharge remained the same during several minutes; and having time to determine the nature of the electricity, by approaching a stick of sealing wax, I saw here on the plain what I have often observed on the back of the Andes, during a storm, that the electricity of the atmosphere was first positive, then null, and then negative. These oscillations from the positive to the negative state were often repeated. We had already observed," he adds, "in valleys of Aragua, from the 18th and 19th of February, clouds forming at the commencement of the night. In the beginning of the month of March the accumulation of the vesicular vapours became visible to the eye, and with them signs of atmospheric electricity augmented daily. We saw flashes of lightning to the South, and the electrometer of Volta displayed constantly at sun set positive electricity. The separation of the little pith balls null during the rect of the day, was from three to four lines at the commencement of the night; which is triple what I generally observed in Europe with the same instrument in calm weather." Again he remarks, "about the end of February and the beginning of March, the blue of the sky is less intense, the hygrometer indicates by degrees greater humidity, the stars are sometimes veiled by a thin stratum of vapours, and their light is no longer steady and planetary; they are seen twinkling from time to time 20° above the horizon. The breeze at this period, becomes less strong, less regular, and is often interrupted by dead calms."

For guarding against accidents from lightning, Dr. Franklin's great invention of metallic conductors may be very advantageously employed; for, when properly fixed, they afford a degree of security, which leaves very little room for apprehension. A conductor ought to be continued deep into the earth, or connected with some well or drain; it should be of ample dimensions, and where smallest, of copper, since copper conducts electricity more readily than iron. In one instance a conductor of iron, four inches wide, and half an inch thick, appears to have been made red hot by a stroke of lightning. It seems to be of some advantage that a conductor should be pointed, but the circumstance is of less consequence than has often been supposed. Mr. Wilson exhibited some experiments in which a point was struck at a greater distance than a ball, and therefore argued against the employment of pointed conductors. Mr. Nairne, on the contrary, showed that a ball is often struck in preference to a point. But it has been observed, that if a point attracts the lightning from a greater distance, it must protect a greater extent of building. It is easy to show, by hanging cotton or wool on a conductor, that a point repels light electrical bodies, and that a pointed conductor may, therefore, drive away some fleecy clouds; but this effect is principally derived from a current of air repelled by the point; and such a current could scarcely be supposed to have any perceptible effect upon clouds so distant as those which are concerned in thunder storms.

A small quantity of metal is found to conduct a great quantity of this fluid. A wire no bigger than a goose-quill, has been known to conduct (with safety to the building, as far as the wire was continued,) a quantity of lightning that did prodigious damage both above and below it; and probably larger rods are not necessary, though it is common in America, to make them of half an inch, and some of three quarters, or an inch in diameter.

The rod may be fastened to the wall, chimney, &c. with staples of iron. The lightning will not leave the rod (a good conductor,) to pass into the wall, (a bad conductor,) through those staples.—It would rather, if any were in the wall, pass out of it into the rod to get more readily by that conductor into the earth.

If the building be very large and extensive, two or more rods may be placed at different parts for greater security.

Small ragged parts of clouds suspended

in the air, between the great body of clouds and the earth, (like leaf gold in electrical experiments,) often serve as partial conductors for the lightning, which proceeds from one of them to another, and by their help comes within the striking distance to the earth or a building. It therefore strikes through those parts of a building that would otherwise be out of the striking distance.

It is therefore proper to elevate the upper end of the rod six or eight feet above the highest part of the building, tapering it gradually to a fine sharp point, which should be gilt to prevent its rusting.

The pointed rod will thus either prevent a stroke from the cloud, or, if a stroke takes place, will conduct it to the earth with safety to the building.

A person apprehensive of danger from lightning, happening, during the time of thunder, to be in a house not so secured, will do well to avoid sitting near the chimney, looking-glass, gilt pictures, or wainscot; the safest place is in the middle of the room, (if not under a metal lustre, suspended by a chain,) sitting on one chair and laying the feet on another. It is still safer to bring two or three mattrasses or beds into the middle of the room, and folding them up double, place the chair upon them; for they not being so good conductors as the walls, the lightning will not chuse an interrupted course through the air of the room and the bedding, when it can go through a continued better conductor, the wall. But where it can be had, a hammock or swinging bed, suspended by silk cords equally distant from the walls on every side, and from the ceiling and floor above and below, affords the safest situation a person can have in any room whatever; and what indeed may be deemed quite free from danger of any stroke by lightning.

ASTRONOMY.

ON THE REGULATION OF TIME BY THE HEAVENLY BODIES.

Though time, considered in an abstract and philosophical point of view, was certainly coeval with the Deity, since nothing can possibly exist but in some portion of it, yet the measuring of time is a matter of a very different nature; and though various nations have differed on this subject, it is, nevertheless, a subject of the utmost importance to every human being. For the opposite and contradictory methods of calculating time have often been productive of very great mischief in the world; while chronologers, sometimes from ignorance, and as often from prejudice, have misrepresented events, which, however trifling they might appear to them, may nevertheless affect the happiness of future ages. During the general *chaos*, or that period when the materials of which the beautiful fabric of the universe was what Ovid calls *rudis indigestaque moles*, a rude and indigested heap, there were no human beings, and consequently no occasion for any method of measuring or regulating time. But as soon as the world was made a fit habitation for man, the measurement of time became necessary on many accounts: our pleasure, as well as our interests, require that this object should be accomplished; but it is only an acquaintance with astronomy that can furnish the means of doing it correctly. For time has always been measured and defined by the motions of the heavenly bodies, and particularly by the sun, as being the most regular and constant in his apparent revolutions.*

The principal divisions of time are the year and the day, which are measured by the annual and diurnal revolution of the sun. The day, or the time in which the sun appears to go round the earth, has been divided into twenty-four equal parts, which are called hours, and these again subdivided into minutes, &c. This division is, however, merely arbitrary; there being no astronomical appearance to warrant or regulate such a division of the day, more than a division into twenty-two, forty-eight, or any other number of equal parts.

The length of the tropical year, or the time the sun is in going from any point of the ecliptic to the same again, is 365 days, 5 hours, 48 minutes, 49 seconds. But the sidereal year, or the time which intervenes between the conjunction of the sun and any fixed star, and his next conjunction with the same star, is 365 days, 6 hours, 9 minutes, $11\frac{1}{2}$ seconds. The difference between these two periods, which amounts to $20' \ 22\frac{1}{2}''$, is occasioned by the recession of the equinoxes, or the falling back of the equinoctial points $50\frac{1}{4}$ seconds of a degree every year. This retrograde motion of the equinoctial points is caused by the joint attraction of the sun and moon upon the earth, in consequence of its spheroidical figure.†

Time is distinguished according to the manner of measuring the day, into *apparent*, *mean*, and *sidereal*. Apparent time, which is also called true, solar, and astro-

* As it may contribute to perspicuity in treating of this important subject, we shall consider the *apparent* motions of the sun as *real*.

† These variations are computed and inserted in a table, which is called a Table of the *Equation of Time*.

nomical time, is derived from observations made on the sun. Mean, or mean solar time, sometimes called *equated time*, is a mean or average of apparent time, which is not always equal; for the intervals between two successive transits of the sun over the meridian are not always the same. This is owing to the eccentricity of the earth's orbit, and its obliquity to the plane of the equinoctial. If the earth's orbit were an exact circle, and coincident with the equinoctial, the sun would always return to the meridian of any place at equal intervals of time, and apparent and mean solar time would be the same. But as this is not the case, mean time is deduced from apparent by adding or subtracting the difference between them, which is usually called the equation of time.

Mean solar days are all equal, being twenty-four hours each; but apparent solar days are sometimes more than twenty-four hours, and sometimes less. A sidereal day is the interval between two successive transits of a star over the same meridian, and is always of the same length; for all the fixed stars make their revolutions in equal times, owing to the uniformity of the earth's diurnal rotation about its axis. The sidereal day is, however, shorter than the mean solar day by $3' \; 56\frac{1}{2}''$. This difference arises from the sun's apparent annual motion from west to east, by which he leaves the star, as it were, behind him. Thus, if the sun and a star be observed on any day to pass the meridian at the same instant, the next day, when the star passes the meridian, the sun will have advanced nearly a degree to the eastward; and, as the earth's diurnal rotation on its axis is from west to east, the star will come to the meridian before the sun; and in the course of a year the star will have gained a whole day on the sun; that is, it will have passed the meridian 366 times, while the sun will only have passed it 365 times. Now as the sun appears to perform the whole of the ecliptic in 365 days, 5 hours, 48 minutes, 49 seconds, he describes $59' \; 8{\cdot}3''$, or nearly one degree of it per day, at a mean rate; and this space reduced to time is exactly $3' \; 56\frac{1}{2}''$, the excess of a mean solar day above a sidereal day.*

The equation of time, or the difference between mean and apparent time, as already mentioned, arises from two causes; namely, the obliquity of the ecliptic to the plane of the equinoctial, and the eccentricity of the earth's orbit. There are, however, four days in the year when the equation of time is nothing, or when the mean and apparent time coincide; these days are, at present, the 15th of April, the 15th of June, the 1st of September, and the 24th of December. From the first of these days to the second, the *apparent* time is before the mean; from the second to the third, the *mean* time is before the apparent; from the third to the fourth, the apparent is before the mean; and from the last of those days to the first, the mean is again before the apparent, and so on alternately.*

If the revolution of the sun consisted of an entire number of days, for instance 365, the year would naturally be made to do the same; and there would be no difficulty in the formation of the *calendar*, or in adjusting the reckoning in years and in days to one another.

All the years would thus contain precisely the same number of days, and would also begin and end with the sun in the same point of the ecliptic. But the sun's revolution includes a fraction of a day, and therefore a year and a revolution of the sun cannot be precisely completed at the same moment. However, as this fraction makes a whole day in four revolutions, one day is added every four years, in order to make this number of years equal to the same number of revolutions. The year to which this day is added therefore contains 366 days.

This is the arrangement of what is called the *Julian Calendar;* and the year thus computed is termed the *Julian* year, from Julius Cæsar, by whom it was introduced at Rome.† But as the real length of the year is 365 days, 5 hours, 49 minutes, nearly, the manner of reckoning adopted by Julius Cæsar was not sufficiently exact to preserve the seasons in the same time of the year: for in four years, the difference between the year thus regulated and the true solar year amounted to about 44 minutes, and in 132 years to one entire day. The Julian year must, therefore, have begun one day earlier than the solar year at the end of this period. Consequently, the continuance of this erroneous mode of reckoning would have made the seasons change their places altogether in the course of twenty-four thousand years.

At the time of the *Council of Nice*, in the year 325 of the Christian era, the Julian calendar was introduced into the Church; and at that time the vernal equinox fell on the 21st of March; but on ac-

* This excess is sometimes called the acceleration of the fixed stars.

* Clocks and watches ought to be regulated by mean time, as none of them can shew apparent time, because they are all constructed on the principle of uniform and equable motion.

† The intercalary day, or the day which was added every fourth year, was accounted the 24th of February, and called by the Romans the 6th of the Kalends of March; on this account there were every fourth year two 6ths of the Kalends of March, and therefore they called this year Bissextile. With us it is called Leap Year.

count of the imperfection of the mode of reckoning just noticed, the reckoning fell constantly behind the true time: so that in the year 1582, the Julian year had fallen nearly ten days behind the sun; and the equinox, instead of falling on the 21st of March, fell on the 11th of March.

The defects of the calendar were discovered long before the year 1582; but all attempts made to reform it proved in vain. At last Pope Gregory, who was desirous of rendering his pontificate illustrious by bringing about a reformation, which his predecessors had failed to accomplish, invited all the astronomers in Chistendom to give their opinions on this important affair. This invitation had the effect of bringing forth many ingenious plans; but the one which he ordered to be adopted was afforded by an astronomer of Verona, named Lilius.

The first step was to allow for the loss of the ten days; which was done by counting the 5th of October, 1582, the 15th of that month. By this means, the vernal equinox was again brought to the 21st of March, as it was at the time of the Council of Nice; and to prevent the like inconvenience in future, it was decreed that the last year of every century, not divisible by *four*, should be accounted a common year, which, according to the Julian reckoning, should be leap year; but that those hundreds which were divisible by four, such as 1600, 2000, 2400, &c. should still be accounted leap year. Although this correction be sufficiently exact to keep the seasons to the same time of the year, yet it does not altogether correspond with the *real length* of the year; for the time that the Julian year exceeds the true will amount to 3 days in 390 years. If, therefore, at the end of 390 years, three days were expunged, the equinox would very nearly keep to the same day of the month; but by suppressing 3 days only in 400 years, as in the Gregorian account, a small deviation will take place in the course of twelve or sixteen centuries, but so trifling as scarcely to deserve notice.

As this reformation of the calendar was brought about under the auspices of Pope Gregory, it is called the Gregorian Calendar, and sometimes the *New Style*, to distinguish it from the Julian account. This new calendar was immediately adopted in all Catholic countries; but it was not adopted in this country till the year 1752. In Russia, Prussia, and some other countries, the Julian account is still used.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF DR. ROBERT SIMSON.

Dr. Robert Simson was born in the year 1687 of a respectable family, which had held a small estate in the county of Lanark for some generations. He was, we think, the second son of the family. A younger brother was professor of medicine in the university of St. Andrew, and is known by some works of reputation, particularly "A Dissertation on the Nervous System," occasioned by the dissection of a brain completely ossified.

Dr. Simson was educated in the university of Glasgow under the eye of some of his relations who were professors. Eager after knowledge, he made great progress in all his studies; and as his mind did not, at the very first openings of science, strike into that path which afterwards so strongly attracted him, and in which he proceeded so far almost without a companion, he acquired in every walk of science a stock of information, which, though it had never been much augmented afterwards, would have done credit to a professional man in any of his studies. He became, at a very early period, an adept in the philosophy and theology of the schools, was able to supply the place of a sick relation in the class of oriental languages, was noted for historical knowledge, and one of the most knowing botanists of his time. As a relief to other studies, he turned his attention to mathematics. Perspicuity and elegance he thought were more attainable, and more discernible in pure geometry, than in any other branch of the science. To this therefore he chiefly devoted himself; for the same reason he preferred the ancient method of studying pure geometry. He considered algebraic analysis as little better than a kind of mechanical knack, in which we proceed without ideas, and obtain a result without meaning, and without being conscious of any process of reasoning, and therefore without any conviction of its truth. Such was the ground of the strong bias of Dr. Simson's mind to the analysis of the ancient geometers. It increased as he advanced, and his veneration for the ancient geometry was carried to a degree of idolatry. His chief labours were exerted in efforts to restore the works of the ancient geometers. The inventions of fluxions and logarithms attracted the notice of Dr. Simson, but he has contented himself with demonstrating their truth on the genuine principles of ancient geometry.

About the age of twenty-five, Dr. Simson was chosen Regius Professor of Mathematics in the University of Glasgow.

He went to London immediately after his appointment, and there formed an acquaintance with the most eminent men of that bright era of British science. Among these he always mentioned Captain Halley (the celebrated Dr. Edmund Halley) with particular respect; saying, that he had the most acute penetration, and the most just taste in that science, of any man he had ever known. And, indeed, Dr. Halley has strongly exemplified both of these in his divination of the work of "Apollonius de Sectione Spatii," and the eighth book of his "Conics," and in some of the most beautiful theorems of Sir Isaac Newton's "Principia." Dr. Simson also admired the wide and masterly steps which Newton was accustomed to take in his investigations, and his manner of substituting geometrical figures for the quantities which are observed in the phenomena of nature. It was from Dr. Simpson that his biographer, to whom we are indebted for this article, learnt, "That the thirty-ninth proposition of the first book of the Principia was the most important proposition that had ever been exhibited to the physico-mathematical philosopher;" and he used always to illustrate to his more advanced scholars the superiority of the geometrical over the algebraic analysis, by comparing the solution given by Newton of the inverse problem of centripetal forces, in the forty-second proposition of that book, with the one given by John Bernoulli in the Memoirs of the Academy of Sciences at Paris for 1713. He had heard him say, that to his own knowledge Newton frequently investigated his propositions in the symbolical way; and that it was owing chiefly to Dr. Halley that they did not finally appear in that dress. But if Dr. Simson was well informed, we think it a great argument in favour of the symbolic analysis when this most successful practical artist (for so we must call Newton when engaged in a task of discovery) found it conducive either to despatch or perhaps to his very progress. Returning to his academical chair, Dr. Simson discharged the duties of a professor for more than fifty years with great honour to the university and to himself. It is almost needless to say, that in his prelections he followed strictly the Euclidian method in elementary geometry. He made use of Theodosius as an introduction to spherical trigonometry. In the higher geometry he lectured from his own Conics: and he gave a small specimen of the linear problems of the ancients, by explaining the properties, sometimes of the conchoid, sometimes of the cissoid, with their application to the solution of such problems. In the more advanced class he was accustomed to give Napier's mode of conceiving logarithms; *i. e.* quantities as generated by motion; and Mr. Cotes's view of them, as the sums of ratiunculæ; and to demonstrate Newton's lemmas concerning the limits of ratios; and then to give the elements of the fluxionary calculus; and to finish his course with a select set of propositions in optics, gnomonics, and central forces. His method of teaching was simple and perspicuous, his elocution clear, and his manner easy and impressive. He had the respect, and still more the affection, of his scholars.

It was chiefly owing to the celebrated Halley that Dr. Simson so early directed his efforts to the restoration of the ancient geometers. He had recommended this to him, as the most certain way for him, at that time very young, both to acquire reputation, and to improve his own knowledge and taste; and he presented him with a copy of Pappus's Mathematical Collections, enriched with his own notes. Hence he undertook the restoration of Euclid's porisms, a work of some difficulty, that his biographer says nothing but success could justify in so young an adventurer. From this he proceeded to other works of importance, which he executed with so much skill, as to obtain the reputation of being one of the most elegant geometers of the age. His edition of Euclid's "Elements" has long been reckoned the very best that exists. Another work, on which Dr. Simson bestowed much labour, was the "Sectio Determinata," which was published after his death, by the late Earl Stanhope, with the great work, "The Porisms of Euclid." This nobleman had kept up a correspondence with Dr. Simson till his death in 1768, when he engaged Mr. Clow, to whose care the Doctor had left his papers, to make a selection of such as would serve to support and increase his reputation, as the restorer of ancient geometry. This selection Lord Stanhope printed at his own expense.

"The life of a literary man rarely teems with anecdote; and a mathematician, devoted to his studies, is perhaps more abstracted than any other person from the ordinary occurrences of life, and even the ordinary topics of conversation. Dr. Simson was of this class; and, having never married, lived entirely a college life.—Having no occasion for the commodious house to which his place in the university entitled him, he contented himself with chambers, good indeed, and spacious enough for his sober accommodation, and for receiving his choice collection of mathematical writers, but without any decoration or commodious furniture. His official servant sufficed for valet, footman, and chambermaid. As this retirement was entirely devoted to study, he entertained no company in his chambers, but in a neighbouring house, where his apartment was sacred to him and his guests. Having in early life devoted himself to the restoration of the works of the ancient geometers, he studied them with unremitting attention; and, retiring from the promiscuous intercourse of the world, he contented himself with a small society of intimate friends, with whom he could lay aside every restraint of ceremony or reserve, and indulge in all the innocent frivolities of life. Every Friday evening was spent in a party at whist, in which he excelled, and took delight in instructing others, till increasing years made him less patient with the dullness of a scholar. The card-party was followed by an hour or two dedicated solely to playful conversation. In like manner, every Saturday he had a less select party to dinner at a house about a mile from town. The Doctor's long life gave him occasion to see the dramatis personæ of this little theatre several times completely changed, while he continued to give it a personal identity; so that, without any design or wish of his own, it became, as it were, his own house and his own family, and went by his name. Dr. Simson was of an advantageous stature, with a fine countenance; and even in his old age had a graceful carriage and manner, and always, except when in mourning, dressed in white cloth. He was of a cheerful disposition; and though he did not make the first advances to acquaintance, had the most affable manner, and strangers were at perfect ease in his company. He enjoyed a long course of uninterrupted health; but towards the close of life suffered from an acute disease, and was obliged to employ an assistant in his professional labours for a few years preceding his death, which happened in 1768, at the age of 81. He left to the university his valuable library, which is now arranged apart from the rest of the books, and the public use of it is limited by particular rules. It is considered as the most choice collection of mathematical books and manuscripts in the kingdom; and many of them are rendered doubly valuable by Dr. Simson's notes." For a more particular account of the life and writings of this great man, the reader is referred to the article in the Encyclopedia Britannica, vol. xvii.

NEW LUNAR AND HORARY TABLES.—By David Thomson.

As it has been our practice from the commencement of the present work to notice any discovery or improvement made in the physical sciences or useful arts, during the progress of the present work, we consider that we shall render an essential service to the cause of navigation, by giving a short account of a work just published, containing tables for facilitating the computation of the longitude at sea.

The importance of the subject is such as to interest all who attach any value either to science or commerce; we shall therefore endeavour to point out the great improvement which the author of these tables has accomplished in the calculation of this laborious and important problem.

Though chronometers, or time-keepers, are now pretty generally used on board of ships, and afford the readiest and most direct method of determining the longitude at sea; yet they are so apt to change their rates of going, and to get deranged, that it not only becomes necessary to correct them at sea, but even to determine the longitude without placing the least dependence upon them. The only accurate and practical method of accomplishing this at sea is, by what is termed the *Lunar method;* which is, to measure the distance between the sun and the moon, or the moon and a star, with a sextant; and from this distance, and the altitudes of the objects, to deduce the *true distance* between them, as the measured distance is seldom or never the same as the true. Now, though some of the best mathematicians and astronomers in Europe have endeavoured to shorten the process of calculation, and various methods have been devised by means of particular sets of tables; yet still it appears so formidable and laborious, that, comparatively speaking, few seamen can be induced to employ this mode of determining the longitude; but will rather trust to the precarious and uncertain one by *dead-reckoning*, which is often one hundred leagues from the truth. And some captains, who have chronometers on board of their vessels, have paid so little attention to the Lunar method, on account of the necessary calculation, that they are under the necessity of making the land for the sole purpose of correcting their chronometers, though it should be many miles out of the direct course they ought to steer.

These are facts that are too well known to admit of dispute or contradiction; and appear to have led the ingenious author of the work before us to think intensely on the nature of this most useful problem; the result of which has been the construction of a small set of tables, by which the *true distance* between the sun and moon, or the moon and a star, may be computed by the addition of a few figures. But, in order to show the shortness and simplicity of the process, we shall give an example, which may be compared with the methods of calculation given in any other work which treats on the same subject.

Suppose the apparent distance between the sun and moon to be 86° 19 10″, the sun's apparent altitude 26° 3′, that of the moon 66° 38′, and the moon's horizontal parallax 55′ 47″: required the true distance?

Moon's hor. par.	0° 55′ 47″	Log. 0·0488	. . . .	Log. 0·0488
Sun's app. alt.	26° 3′ 0″	Log. 0·8174	Moon's ap. alt. 66° 38′	Log. 0·4972
App. dist.	86° 19′ 10″	Log. S 0·9991	. . . .	Log. T 2·1913
First correc.	4° 35′ 27″	Log. 1·8653		
Second correc.	5° 3′ 18″	. . .	. . . .	Log. 2·7373
Third correc.	0° 2′ 10″			
Sum—10=True Dist.	86° 0′ 5″			

The numbers here called Logs. are directly obtained from the tables, which are so arranged as to admit of the quantities being taken out nearly at one opening of the book.

The manner of computing the true distance between the moon and a star being exactly similar to the above, it is unnecessary to give any example.

The manner of finding the time as well as the altitudes of the objects, are also very easily performed by the precepts and tables contained in this work. But what we consider next in importance to the simple and concise method here given of computing the *true distance*, is the full and lucid manner in which the method of ascertaining the longitude by Chronometers is illustrated and explained; and we have no hesitation in saying, that the observations on the method of managing and determining the rate of these delicate machines at sea, are such as display an intimate acquaintance both with the theory and practice of navigation.

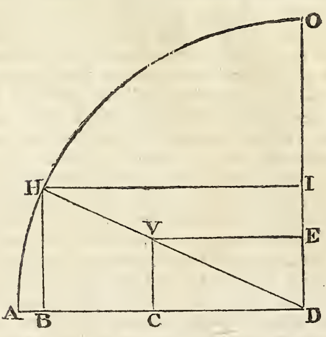
To the practical seaman this must therefore prove a very valuable work; and as it is of a moderate price, the humblest individual who goes to sea may procure it.

We may add, that the typographical execution and appearance of this work is superior to any book of figures we have ever seen.

SOLUTIONS OF QUESTIONS.

QUEST. 63, *answered by* Mr. WHITCOMBE, *Cornhill (the Proposer).*

Let A O D be the given quadrant, then in A D take D C to D E, as m to n, and



draw C V parallel to D O and equal to D E; join E V, also D V, and continue it till it cuts A O in H; then draw H B parallel to D O, and H I to A D; then H B D I will be the rectangle required.

DEMON. Because H B, V C, and D I are parallel; also H I, V E, and B D, the triangles H B D and V C D are similar; therefore C D : C V :: B D : B H; but C D : C V or D E :: $m : n$; consequently B D : B H :: $m : n$. Hence B H I D is the rectangle required.

Though this is a very beautiful and simple problem, yet the above is the only solution of it which we have received. We are sorry that *Geometry* should be so little studied by our mathematical correspondents, as it appears to us to be; for we have observed during the progress of the present work, that few of our correspondents have paid much attention to this elegant and beautiful branch of the Mathematics. ED.

QUESTION FOR SOLUTION.

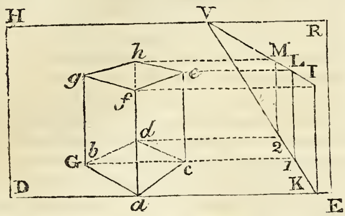
QUEST. 65, *proposed by* Mr. J. TAYLOR, *Clement's-lane, Lombard-street.*

Two ladies subscribe to a certain charity certain sums of money, in the ratio of 4 to 5; now the sum of the squares of each person's subscription amounted to 69*l.* 5*s.* $9\frac{6}{10}$*d.* I demand the sum subscribed by each lady?

PERSPECTIVE.

To exhibit the perspective of a cube with one of its angles presented to the eye.

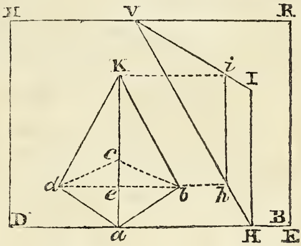
As the basis of a cube, with one of its angles presented to the eye, and standing on a geometrical plane, is a square with one of its angles presented to the eye; draw a square, viewed angular-wise, on the perspective to *b b*, or plane. Raise the side H I of the square perpendicularly



on each point of the terrestrial line D E; and to any point, as V, of the horizontal line H R, draw the right lines V I and V K. From the angles *d*, *b*, and *c*, draw *c* 1, *d* 2, &c. parallel to the terrestrial line D E. From the points 1 and 2, raise L 1 and M 2, perpendicular to the same. Lastly, since K I is the height to be raised in *a*, L I in *c* and *b*, and M 2 in *d*; in *a* raise the line *f a* perpendicular to *a* E; in *b* and *c*, raise *b g* and *c e* perpendicular to *b c* 1: and lastly, raise *d h* perpendicular to *d* 2; and make *af* equal to H I, *b g* equal to *e c*, and also L 1, and *h* equal to *d* M 2: if, then, the points *g*, *h*, *e*, *f* be connected by right lines, the perspective will be complete.

To exhibit the perspective of a pyramid standing on its base.

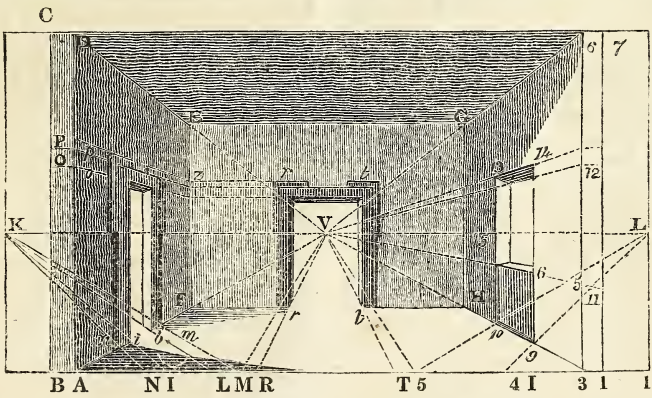
Suppose it were required to delineate a quadrangular pyramid, with one of its angles presented to the eye: since the base of such a pyramid is a square, presenting one of its angles to the eye, construct such a square. To find the vertex of the pyramid; that is, a perpendicular let fall from the vertex to the base, draw diagonals mutually intersecting each other in *e*.



On any point, as H, of the terrestrial line D E, raise the altitude of the pyramid H I; and, drawing the right lines H V and I V, to each point of the horizontal line H R, produce the diagonal *a b*, till it meet the line V H in *h*. Lastly, from *h* draw *h i* parallel to H I. This being raised on the point *e*, will give the vertex of the pyramid K; consequently, the lines *d k*, *k a*, and *k b*, will be determined at the same time.

To exhibit the perspective of walls, columns, &c. or to raise them on the pavement.

Suppose a pavement A F H I represented in a plan, together with the basis of



the columns, &c. if there be any. Upon the terrestrial line set off the thickness of the wall B A and 1, 3. Upon A and B, as also upon 3 and 1, raise perpendiculars A D and B C; as also 3, 6, and 1, 7. Connect the points D and 6 with the principal point V, by the right lines D V and 6 V. Upon F and H raise perpendiculars H G and E F. Thus will all the walls be delineated. Now to raise the pillars, &c. there needs nothing but, from their several bases (whether square or circular) projected on the perspective plan, to raise indefinite perpendiculars; and on the fundamental line, where intersected by the radius F A passing through the base, raise the true altitude A D: for D V being drawn as before, the perspective altitudes will be determined.

To exhibit the perspective of a door in a building. (See last figure.)

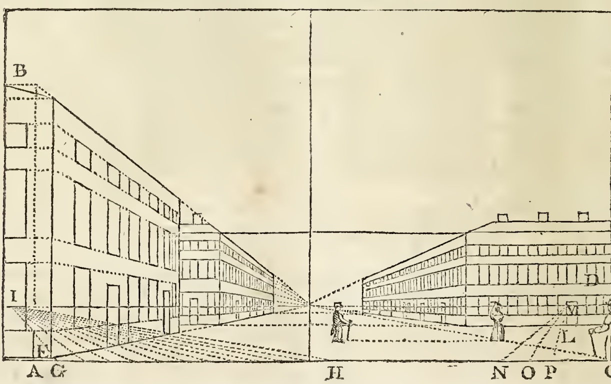
Suppose a door required to be delineated in a wall D E F A: upon the fundamental line set off its distance A N from the angle A, together with the breadths of the posts N I and L M, and the breadth of the gate itself L I. To the point of distance K, from the several points N, I, L, M, draw right lines K N, K I, K L, K M, which will determine the breadth of the door *l i*, and the breadths of the posts *i n* and *m l*. From A to O, set off the height of the gate A O, and from A to P, the height of the posts A P. Join O and P with the principal point, by the right lines P V and O V. Then, from *n*, *i*, *l*, *m*, raise perpendiculars, the middle ones whereof are cut by the right line O V in *o*, and the extremes, by the right line V P in *p*. Thus will the door be delineated, with its posts. If the door were to have been exhibited in the wall E F G H, the method would have been nearly the same. For, upon the terrestrial line, set off the distance of the door from the angle, and thence also the breadth of the door R T. From R and T draw right lines to the principal point V, which give the breadth *r t* in the perspective plan. From *r* and *t* raise indefinite perpendiculars to F H. From A to O, set off the true height A O. Lastly, from O to the principal point V, draw the right line O V, intersecting E F in Z, and make *r r* and *t t* equal to F Z. Thus is the door *r r*, *t t*, drawn; and the posts are easily added, as before.

To exhibit the perspective of windows in a wall. (See last figure.)

When it is known how to represent doors, there will be no difficulty in adding windows; all that is further required, being to set off the height of the window from the ground: the whole operation is as follows:—From 1 to 2 set off the thickness of the wall at the window; from 3 to 4, its distance from the angle 3; and from 4 to 5 its breadth. From 4 and 5, to the point of distance L, draw the right lines L 5 and L 4, which will give the perspective breadth 10, 9 of the window. From 10 and 9 raise lines perpendicular to the pavement; that is, draw indefinite parallels to 6 and 3. From 3 to 11 set off the distance of the window from the pavement 3 and 11; and from 11 to 12, its height 11 and 12. Lastly, from 11 and 12, to the principal point V, draw lines V 11 and V 12; which intersecting the perpendiculars 10, 13, and 9, 14, in 13 and 14, as also in 15 and 16, will exhibit the appearance of the window.

From these examples, which are all no more than applications of the first grand or general rule, it will be easily perceived what method to take to delineate any other object, and at any height from the pavement.

When it is required to determine a point in a line parallel to the picture, we may suppose a line to be drawn through it perpendicular to the picture, and, by finding the image of this line, we may intersect the former image in the point required. It is thus, that any number of columns or figures, at different distances, may be readily determined. Thus, the heights of the houses, windows, doors, and figures in the following representation of a street, are determined by lines directed to the centre of the picture; the true height being measured on the lines A B, C D, where the objects are supposed to touch the plane of projection.



The distance E F, and all other parts of lines perpendicular to the picture, are measured by laying off the lengths of the originals, as G H, on the line A C, and drawing I E G I E H from I, the point of distance; which, in most cases, will be more remote from the centre of the picture than is here made. The line K L, and others parallel to A C, may be measured by the assistance of any point M in the horizontal line, the distances N O, O P, being laid off on A C, or simply by reducing the scale in the proportion of M P to M L.

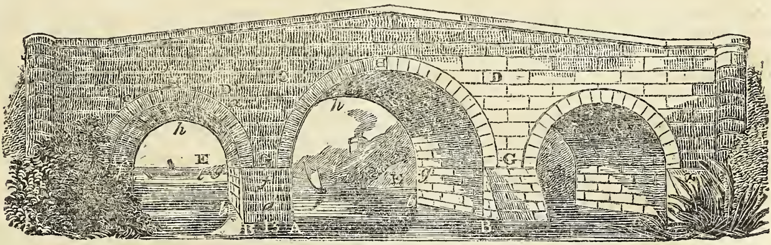
To form a bridge in perspective, a front view.

Let the station of the observer be opposite the centre of the nearest arch, his eye elevated 15 feet above the water, or plane of the base, and viewed under an angle of 60 degrees.

Let the length of the bridge be 181 feet, and consist of 3 arches; the first arch to the left hand 50 feet; the second 70; and the third 35; the piers 13 feet each, about one-fifth of the opening of the 70 feet arch being the ordinary thickness of them, although much less is sufficient; but this is not a place for discussion. The height of the pier to the spring of the arch, 20 feet, and the arches semicircles; the width of the bridge, including the parapets of the road-way, 40 feet; the height of the road-way may be about 62 feet, if a semicircle; if an ellipse upon the greater diameter, or if a segment of a circle, the height may be much less; and if Gothic arches are used, they may be considerably greater, which circumstances must regulate.

To form the bridge, and parts, from a one-fourth inch scale.

Let A B be the ground line, of an indefinite length.



With the span of the arch 50, and width 40, describe the perspective parallelogram A B *b a*, by prob. 4; at the point A, draw A C perpendicular to the ground line, and equal to the height of the pier, and radius of the circle, which is 45 feet; draw C D equal and parallel to A B; upon C D, and with the same breadth 40, describe the perspective parallelogram C D *d c*; set off A F, B G, each equal 20 feet, the height of the spring of the arch; join F G, and upon F G describe the parallelogram F G *g f*; bisect *f g* in the points E, *e*; with the centre E, *e*, and distances E G, *e g*, describe the semicircles F H G, *f h g*; which represent the front and opposite opening of the arch.

To form the arch on the right hand of the front opening. Upon the ground line A B, set off from B the thickness of the pier 13 feet to A′; from A′ set off A′ B′ equal to 70 feet; upon A′ B′ 70, with the width 40, describe the parallelogram A′ B′ *b′ a′*; raise the perpendiculars A′ C′, B′ D′, equal 55 feet; mark off A′ F′, B′ G′ 20 feet, for the spring of the arch, as before; join C′ D′, and upon C′ D′, F′ G′, with the width 40, describe the parallelograms G′ F *g′ f′*, C′ D′ *d′ c′*; find the centres E, *e*, as in the last; with the centres E, *e*, and distance E F, *e f*, describe the semicircle, G H F, *g h f*; G H F representing the front of the opening of the arch, and *g h f* the back opening, of which part is hid by the pier. In the same manner, any number of similar arches may be formed, either upon the right or left hand; and the opening of the arches will decrease in the same manner, and for the same reasons, as were shewn in forming windows.

To form the arch stones. These are here measured 3 feet, in the 50 feet arch, and 4 feet in the 70, and 1 foot thick; in the 50 feet arch, the measure of one foot is from the outside of the architrave; and in the 70 feet arch, the measure of 1 foot is taken from the inside of the architrave. In drawing the arch stones, the lines are all directed to the centre of curvature; but in forming the perspective of the inside of the arch, the lines are all directed to the point of sight, whether they proceed from the curvature of the arch, or from the inside of the piers.

If the curvature is represented in the circular part of the arch, the distance of the centres E, *e*, being divided into as many parts as there are stones in the width of the bridge; or into so many parts as would render the circles distinct, each of these points would be centres of the different circles, which might be drawn till intercepted by the side of the pier and arch. The opposite bank of the river is in the direction *i x*; such objects as come in view upon it may be represented.

The abutments, or land-stools, may be formed at pleasure, the situation of the banks of the river must regulate the form of the arch, as to its height; and the situation of the observer, must be regulated by what is intended for the view; if his station is on a level with the road-way, a considerable part of the field may come into view, but most of the inner part of the arch will be hid.

To form the cut-water of the pier. This may be angular, or rounded off at pleasure; suppose it to be formed by an equilateral triangle, described upon the breadth of the pier 13 feet, the perpendicular height of that triangle is 11 feet nearly; which set off on the ground line A B; from the point A draw the radials *i* A, *i* 11, and from the distance point *z*, draw *z* 11, till it cut the radial A *i* produced in *r*; draw *r s* parallel to A B; bisect the piers B A′, draw radials through the points of section, till they cut the parallel *rs*; then these points of section will give the vertexes of the cut-water; join the vertex and sides of the piers, which will give the true representation of the cut-water. In the same manner form the top.

CHEMISTRY.

We are yet ignorant of the union of copper with the first combustible substances; particularly with azote, hydrogen, and carbon, with which it is even believed to be incapable of combining. All we know is, that hydrogen and carbon decompose the oxide of this metal, take from it its oxygen, and reduce it to the metallic state, at a red heat.

Copper is capable of combining with most of the metals; and some of its alloys are of very great utility.

The alloy of gold and copper is easily formed by melting the two metals together. This alloy is much used, because copper has the property of increasing the hardness of gold, without injuring its colour. Indeed, a little copper heightens the colour of gold, without diminishing its ductility. This alloy is more fusible than gold, and is therefore used as a solder for that precious metal. Copper increases likewise the hardness of gold. According to Muschenbroek, the hardness of this alloy is a maximum, when it is composed of seven parts of gold, and one of copper. Gold alloyed with $\frac{1}{12}$th of pure copper, by Mr. Hatchett, was perfectly ductile, and of a fine yellow colour, inclining to red. Its specific gravity was 17·157. This was below the mean. Hence the metals have suffered an expansion. Their bulk before union was 2732, after union 2798. So that $916\frac{2}{3}$ of gold, and $83\frac{1}{3}$ of copper, when united, instead of occupying the space of 1000, as would happen were there no expansion, become 1024.

Gold coin, sterling or standard gold, consists of pure gold alloyed with $\frac{1}{12}$ of some other metal. The metal used is always either copper or silver, or a mixture of both, as is most common in British coin. Now it appears, that when gold is made standard by a mixture of equal weights of silver and copper, that the expansion is greater than when the copper alone is used, though the specific gravity of gold alloyed with silver differs but little from the mean. The specific gravity of gold alloyed with $\frac{1}{24}$th of silver and $\frac{1}{24}$th of copper was 17·344. The bulk of the metals before combination was 2700, after it 2767.* We learn from the experiments of Mr. Hatchett, that our standard gold suffers less from friction than pure gold, or gold made standard by any other metal besides silver and copper; and that the stamp is not so liable to be obliterated as in pure gold. It therefore answers better for coin. A pound of standard gold is coined into $44\frac{1}{2}$ guineas, or $46\frac{7}{10}$ sovereigns.

Platinum may be alloyed with copper by fusion, but a strong heat is necessary. The alloy is ductile, hard, takes a fine polish, and is not liable to tarnish. This alloy has been employed with advantage for composing the mirrors of reflecting telescopes. The platinum dilutes the colour of the copper very much, and even destroys it, unless it be used sparingly. For the experiments made upon it we are indebted to Dr. Lewis. Strauss has lately proposed a method of coating copper vessels with platinum instead of tin; it consists in rubbing an amalgam of platinum over the copper, and then exposing it to the proper heat.

Silver is easily alloyed with copper by fusion. The compound is harder and more sonorous than silver, and retains its white colour even when the proportion of copper exceeds one-half. The hardness is a maximum when the copper amounts to one-fifth of the silver. The standard or sterling silver of Britain, of which coin is made, is a compound of $12\frac{1}{3}$ silver and one copper. Its specific gravity after simple

* The first guineas coined were made standard by silver; afterwards copper was added to make up for the deficiency of the alloy; and as the proportion of the silver and copper varies, the specific gravity of our gold coin is various also.

fusion is 10·200. By calculation it should be 11·33. Hence it follows that the alloy expands, as is the case with gold when united to copper. A pound of standard silver is coined into 66 shillings.

Mercury acts but feebly upon copper, and does not dissolve it while cold; but if a small stream of melted copper be cautiously poured into mercury, heated nearly to the boiling point, the two metals combine, and form a soft white amalgam.

There is no metal more useful than copper, excepting iron, to which it yields the superiority. Every one knows that a great number of instruments and utensils are made of copper for various purposes. Those vessels which are to be placed upon the fire are generally made of it, as it is much less liable to alteration than iron, and at the same time much more easy to be wrought. Its alloys with zinc and tin are employed for a great number of purposes in the arts, and in common life. But, unfortunately, this metal acts as a poison upon the animal economy; and it is one of the bodies that most threaten our existence. It is therefore much to be wished that it were prescribed, at least for economical and domestic uses. Cisterns, reservoirs, pipes, and cocks, made of this metal, or its alloys, are no less dangerous than copper-pans; and frequently they are even more pernicious, as they are not kept with the same care as the vessels, the whole of which is exposed to view at once, and which are employed several times a day. Too much care, attention, and prudence, cannot be employed in the use of all utensils made of copper, as all its oxides are extremely susceptible of dissolving in fat, oils, and most of the unctuous substances that are employed in the preparation of food. Frequent tinning is the most certain defence against this terrible evil.

Besides the varied and multiplied uses of copper in the metallic form, several ores and preparations of this metal are employed in a great number of the arts. The pyrites sulphurets serve for the preparation of the sulphate of copper, by their spontaneous efflorescence and their lixiviation; it is also prepared by burning a mixture of sulphur and copper. The malachites are cut and polished for trinkets; copper is continually alloyed with zinc and tin for making brass, casting statues, bells, pieces of artillery, &c. Its different salts and oxides enter into the preparation of colours for painting; of the baths; the preparations and mordants for dyeing; of enamels and glazings for pottery and porcelain; and of coloured glasses.

OF IRON.

Iron is the most important and most useful of all metallic substances. Without this metal no art could have arisen; man had remained in the savage state, and disputed for his food by brute strength with the other animals. Without this metal, agriculture could not have existed, nor could the plough have rendered the earth fertile. Without iron, all the other metals would have been of no utility; for it is by means of this agent that they receive their varied forms and dimensions. Iron alone may be considered as the representative of every other metal; it may be substituted in the place of any of them, but no metal can afford a substitute for iron. Though the scarcity, the brilliancy, and durability of gold and silver may place them in a higher rank in these respects, yet the service which iron renders to society entitles it to a higher degree of estimation in the minds of men, who are accustomed to think with justice and propriety. It is true, that it does not shine with a splendour equally strong; nature has not decorated it with so beautiful a colour, but its intimate properties are much more precious. All the other metals might, in truth, be dispensed with; but iron, on the contrary, is indispensible and necessary. The condition of humanity would be truly miserable without this metal, as is proved by the history of those people with whom the art of working it is still unknown, and who, with joy and exultation, exchange the gold with which their country is enriched for morsels of iron, which happier and more cultivated nations bring to them in exchange. Iron composes the first instrument of machines, and the first mover of mechanics. In the hands of men it governs, and, as it were, subdues all the products of nature. In successive obedience to his power, we behold it change the form and properties of other bodies, by the perpetual influence it exercises upon them. In a word, it is the soul of all the arts, and the source of almost every beneficial product.

Though a thousand facts in history prove that the ancients were not acquainted with the art of working iron like the modern nations, the historians of Chemistry have nevertheless placed the infancy of their science among the first operators at the forge, whose existence they have admitted almost in the first ages of the world.

The Alchemists qualified iron with the name of Mars, by consecrating it to the god of war, in whose service it has been much employed. From the denomination of Mars given to iron, naturally flowed the appellation *martial*, which has been successively attributed to numerous preparations made with this metal.

Iron possesses a peculiar metallic brilliancy. When we wish to describe its colour, we are obliged to say that it is white, rather livid, inclined to grey and to blue. In its texture it is formed of small fibrous threads, or small grains and small plates very pointed. When examined with the microscope, it presents a great number of pores or small cavities, more perceptible than in copper. It appears that its interior texture, as shewn in its fracture, which is more or less fibrous, granulated or lamellated, depends much on the method of its cooling, the pressure it has undergone, the manner of treatment, and the heat under which it has been forged or struck.

The specific gravity of iron varies from 7·600 to 7·800. Its hardness exceeds that of any other metal, and on this account it is used to grind, cut, fashion, engrave, and file most natural bodies, stones, wood, and particularly the other metals. It is also the most elastic of metals, and is therefore preferred to all the others for springs of every description.

The ductility of iron is also very considerable; but it is in some sort of a particular kind, or rather it is limited by its excessive hardness, or the cohesion of its particles. Though these adhere much more strongly than most of the other metallic substances, it cannot be made into plates as thin as are formed of several other of the latter; the thinnest sheet iron is in fact much thicker than very coarse leaves of lead or tin. For this reason iron is commonly placed in the fourth rank among metals as to its ductility, and this place is given on account of its ductility in the wire-drawers' plates. Its malleability is very limited, on account of its firmness, so that its ductility is much more eminent and remarkable. A wire of this metal, of one-tenth of an inch in diameter, supports a weight of four hundred and fifty pounds before it breaks, which cannot be done with any other metal, not even copper and platina, which approach the nearest to it. Muschenbroeck, by examining a paralellopipedon of iron, of one-tenth of an inch in diameter, was obliged to use a force of seven hundred and forty pounds to break it; and he remarks on this occasion, that a similar piece of iron, forged of horse-shoe nails, which had remained for some time in the hoof of a horse, did not exhibit a greater tenacity. This opinion is therefore a prejudice which arises only from the goodness and purity of iron made use of for forging those nails. When heated to about 158° of Wedgewood's pyrometer, as Sir George M'Kenzie has ascertained, it melts. This temperature being nearly the highest to which it can be raised; it has been impossible to ascertain the point at which this melted metal begins to boil and evaporate. Neither has the form of its crystals been examined: but it is well known that the texture of iron is fibrous; that is, it appears when broken to be composed of a number of fibres or strings, bundled together.

Iron is rapidly penetrated by the electric fluid; it is one of the best conductors of electricity; and accordingly, since the discoveries of Franklin on the identity of atmospheric thunder and electric spark, it is employed with great success to fabricate those elevated conductors, which are appropriated by their gilded and unalterable terminations in a point, to attract without noise, and rapidly to transport the electric matter into the earth or into water, where their inferior extremities terminate. It has been long observed, that iron, thus vertically placed in an elevated situation of the atmosphere, if it remains a long time, or be struck with the electric fluid of lightning, it assumes the properties of a magnet. If iron be struck in the air by the electric shock, it takes fire; but as this phenomenon belongs to the history of its combustion, we shall speak of it in another place.

Magnetism is one of the most characteristic, and, at the same time, most singular of the properties of iron. It was long supposed to be peculiar to this metal; but it is now well known, that cobalt and nickel also possess it. Nevertheless, all the experiments relative to the magnetism of these two last metals not having been made either with the same accuracy, or to the same extent, as upon iron, the principal phenomena of this force have been well observed only in the latter metal.

The taste and smell are also two very distinct and very evident properties in iron. If we hold a piece of iron for some time in the hand, and afterwards hold it a little distance from the nose, we may discern its odour and quality.

When exposed to the air, its surface is soon tarnished, and it is gradually changed into a brown or yellow powder, well known under the name of rust. This change takes place more rapidly if the atmosphere be moist. It is occasioned by the gradual combination of the iron with the oxygen of the atmosphere, for which it has a very strong affinity.

Carburet of iron is found native, and has been long known under the names of *plumbago* and *black lead*. It is of a dark iron grey or blue colour, and has something of a metallic lustre. It has a greasy feel, is soft, and blackens the fingers, or any other substance to which it is applied It is found in many parts of the world, especially in Britain,* where it is manufactured into pencils. It is not affected by the

* The chief mines are at Keswick in Cumberland, and in Airshire.

most violent heat as long as air is excluded, nor is it in the least altered by simple exposure to the air or to water. A moderate heat produces no effect upon it, and occasions but little change in its bulk. It is used, therefore, in making the crucibles called *black lead.* It was long supposed to be incombustible.

OF TIN.

Tin is one of the metals which was earliest known, and of which the discovery must have been among the first which was made by men; at least, its discovery appears to be hidden in the darkness of ancient times, even beyond those of fabulous history. The Egyptians made great use of it in their arts; and the Greeks alloyed it with other metals. Pliny, without composing an accurate history, or precisely comparing its qualities with other metals, speaks of it as a metal well known, and much employed in the arts, and even applied to a great number of the ornaments of luxury. He often calls it white lead, and points out its frequent and fraudulent contamination with black lead, or lead properly so called.

The alchemists attended greatly to tin; they named it Jupiter, and have distinguished its various preparations by the name of Jovial.

Pure tin is of a white colour, equal in beauty and brilliancy to that of silver; and if this colour were not changeable, it would be as valuable as silver. It was formerly considered as the lightest of metals, when a distinct and particular class was made of the semi-metals. Its specific gravity varies from 7·291 to 7·500, according as it is hammered or not.

It is one of the softest of metals. It may be easily scratched with the nail; and there is scarcely any other metal which cannot injure its surface by pressure or by friction. A knife readily cuts it; it may be easily bended, and when bended, affords a peculiar crackling noise. In this property it has been compared to zinc; but the noise is very different, or much weaker, in zinc than in tin.

This phenomenon appears to depend on a separation of its parts, and the sudden fracture which they suffer by the bending, though tin is not easily broken. Its sonorous quality is feeble; its ductility is sufficient to admit of its being reduced by the hammer, or laminating cylinder, into very thin leaves, which are of great use in the arts. It holds the fifth rank among metals in this property. It has little elasticity or tenacity; a wire of this metal of $\frac{1}{10}$ of an inch in diameter supports, without breaking, a weight of 50 pounds.

Tin is one of the most dilatable of metals by caloric, according to the experiments o Muschenbroeck.

It is also a good conductor of heat. After mercury, it is the most fusible of all the metals. It comes immediately before bismuth and lead in this respect; its melting point is 440° of Fahrenheits's scale. When fused, it does not rise in vapour, but at a very elevated temperature; it has ever been considered as one of the most fixed of metals; on which account the alchemists thought it considerably resembled silver. If it be suffered to cool slowly, and when its surface is congealed it be pierced, and the part which is still fluid be carefully poured out, the interior presents crystals in rhombs of considerable size, formed by the assemblage of a great number of small needles longitudinally united.

Tin is a very good conductor of electricity and galvanism, and is frequently used for covering conductors, and for Leyden bottles. It has a very remarkable odour, with which it impregnates the hands and bodies rubbed with it. Its taste is also very sensible, and it also possesses very powerful medicinal properties.

Tin is not very abundant in the bowels of the earth, at least in Europe. The most abundant mines are in Cornwall, Bohemia, and Saxony. The most skilful mineralogists have hitherto distinguished only three species of tin ores; namely, native tin, its oxide, and its sulphurated oxide.

Tin is not easily oxidized in the air without heat, but it soon loses its bright and beautiful white colour. When cut, it is as brilliant and as clear as silver; but in a few hours this fine colour changes, becomes dull, and in a few days becomes tarnished. Long exposure to the air considerably increases this alteration, though it takes place only at the surface; so that at last it becomes of a dirty grey, without any brilliancy, and is covered with a light stratum of grey oxide. It is, therefore, necessary that vessels of tin should be frequently cleaned and brightened to renew their surface and retain their beauty. But this weak oxidation never penetrates so deeply as to justify the assertion that tin, like other metals, rusts in the air.

When tin is fused with the contact of the air, the metal, when scarcely liquefied, becomes covered with a dull grey pellicle, which becomes wrinkled, and separates from the portion of fused tin. When this pellicle is detached, another is formed; and by proceeding in the same manner, the whole of the tin may be converted into pellicles.

In the art of casting and purifying tin vessels, this oxidized matter, formed at the surface of the metal in fusion, was called dross; and it is very evident that it is in the power of the founder, to convert all the tin into dross; he consequently did not lose this pretended impurity, but knew very well how to recover it again in its metallic form, by heating it with tallow or resin. This crust is, therefore, a true grey oxide of tin; the metal contains from eight to ten per cent. of oxygen, and it is easily reduced. If tin be continually heated with the contact of air, particularly with agitation, it become divided, attenuated, and is changed into a powder, which gradually becomes white, with increase of weight, is more oxidized, and constitutes what is called putty of tin in the arts.

OF LEAD.

The alchemists compared lead to Saturn, not only because they suppose this metal to be the oldest, and, as it were, the father of all the others, but also because it was considered as very cold, and possessing the property of absorbing and apparently destroying almost all the other metals; in the same manner as fabulous history affirms that Saturn, the father of the gods, devoured his children.

Lead is of a blueish white colour, and when newly melted is very bright; but it soon becomes tarnished by exposure to the air. It has scarcely any taste, but emits on friction a peculiar smell. It stains paper or the fingers of a blueish colour. When taken internally, it acts as a poison.

Its specific gravity is 11·3523, but it is not increased by hammering; so far from it, that Muschenbroeck found lead when drawn out into a wire, or long hammered, to be diminished in its specific gravity. A specimen at first of the specific gravity 11·479 being drawn out into a fine wire, was of the specific gravity 11·317; and on being hammered, it became 11·2187; yet its tenacity was nearly tripled.

It is very malleable, and may be reduced to very thin plates by the hammer; it may be also drawn out into a wire, but its ductility is not great. Its tenacity is such, that a lead wire $\frac{1}{10}$ of an inch diameter is capable of supporting only $29\frac{3}{4}$ pounds without breaking.

Lead is a very good conductor of caloric, though it is not extremely dilatable. It melts at a low heat, and immediately after mercury, tin, and bismuth; it holds the fourth rank in the order of fusibility. Mr. Crichton, of Glasgow, estimates it at 612 degrees of Fahrenheit's thermometer. When it is kept long red hot, it sublimes, and emits fumes in the air; but for this purpose a very elevated temperature is required. If it be slowly cooled, it crystallizes in quadrangular pyramids, all formed, as it would appear, of octahedrons. Thus it was that Mongez, the younger, obtained it. It is observable that when this operation is performed, it succeeds best (as tin likewise does) when the lead has been fused several times successively.

This metal is a conductor of electricity and galvanism; but it appears that it possesses these properties only in a weak degree. It has a particular and rather fetid smell; its taste is also somewhat acrid and disagreeable; in consequence of this property, it would seem that it acts upon the animal economy, and produces the deadening and paralysing action which is so well known.

The ores of lead are very abundant in nature, particularly in France, Germany, England, &c. It is also a metal of which the ores are the most varied.

The treatment of the ores of lead in the large way is one of the most important of metallurgical operations, and one of those which have the greatest as well as the most intimate connection with the knowledge and accurate processes of Chemistry. The sulphurous ores containing silver are wrought by pounding them in a stamping engine, and carefully washing them on platforms, and then carrying them to the blast-furnace, where they are first roasted by a gentle heat, and afterwards fused by increase of temperature. The fused lead is drawn off from the furnace by opening a hole on one of the sides of its hearth, which, during the fusion, is kept closed with loam. The lead is first cast into pigs, which are called work-lead, because it is intended to be used in subsequent operations to separate the silver which it contains.

Lead exposed to the air becomes speedily tarnished, soon looses the slight brilliancy which characterises it, becomes of a dirty grey colour, and afterwards of a light grey, which constitutes a true rust at its surface.

When thin plates of lead are exposed to the vapour of warm vinegar, they are gradually corroded, and converted into a heavy white powder, used as a paint, and called *white lead.* This powder was formerly considered to be a peculiar oxide of lead; but it is now known that it is a compound of the yellow oxide and carbonic acid.

The grey oxide of lead, when strongly heated for a considerable time in contact with the air, soon becomes yellow by a new absorption of oxygen. In this state of yellow oxide it is called *massicot* in the arts; it appears that it contains from six to nine parts of oxygen in the hundred. It is distinguished into two kinds in commerce on account of its colour: the one is called *white massicot*, and the other *yellow massicot.* It is a pigment of a dull hue, without any beauty; sometimes inclining to green, which nevertheless is prepared in the large way in certain manufactories, on account of the uses to which it is applied in the arts. The method of producing it consists simply in perpetually agitating the lead in contact with the air, without using a violent heat.

If massicot, ground to a fine powder, be put into a furnace, and constantly stirred while the flame of the burning coals plays against its surface, in about 48 hours it is converted into a beautiful red powder, known by the name of *minium* or *red lead*. This powder, which is likewise used as a paint, and for various other purposes, is the *tritoxide*, or *red oxide* of *lead*.

Lead and tin may be combined in any proportion by fusion. This alloy is harder, and possesses much more tenacity than tin. Muschenbroeck informs us that these qualities are a maximum when the alloy is composed of three parts of tin and one of lead. The increased hardness seems to prevent in a great measure the noxious qualities of the lead from becoming sensible when food is dressed in vessels of this mixture. What is called *ley pewter* in this country is often scarcely any thing else than this alloy.* *Tinfoil* is also a compound of tin and lead.

ASTRONOMY.

OF THE TIDES.

The tides have always been found to follow, periodically, the course of the sun and moon; and hence it has been suspected, in all ages, that the tides were, some way or other, produced by these bodies.

The celebrated Kepler was the first person who formed any conjectures respecting their *true* cause. But what Kepler only hinted, has been completely developed and demonstrated by Sir Isaac Newton.

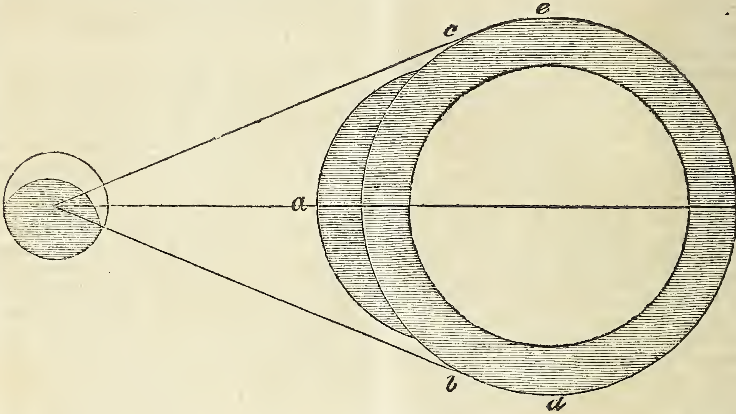
After his great discovery of the law of gravitation, he found it an easy matter to account for the whole phenomena of the tides: for, according to this law of nature, all the particles of matter which compose the universe, however remote from one another, have a continual tendency to approach each other, with a force directly proportional to the quantity of matter they contain, and inversely proportional to the square of their distance asunder. It is therefore evident, from this, that the earth will be attracted both by the sun and moon. But although the attraction of the sun greatly exceeds that of the moon, yet the sun being nearly four hundred times more distant from the earth than the moon, the *difference* of his attraction upon *different* parts of the earth is not nearly so great as that of the moon; and therefore the moon is the principal cause of the tides.

If all parts of the earth were equally attracted by the moon, it would always retain its spherical form, and there would be no tides at all. But the action of the moon being unequal on different parts of the earth, those parts being most attracted that are nearest the moon, and those at the greatest distance least, the spherical figure must suffer some change from the moon's action. Now as the waters of the ocean directly under the moon are nearer to her than the central parts of the earth, they will be more attracted by her than the central parts. For the same reason, the central parts will be more attracted than the waters on the opposite side of the earth, and therefore the distance between the earth's centre and the waters on its surface, both under the moon and on the opposite side, will be increased; or the waters will rise higher, and it will then be flood, or high water, at those places. But this is not the only cause that produces the rise of the waters at these two points; for those parts of the ocean which are 90° from them will be attracted with nearly the same force as the centres of the earth, the effect of which will be a small increase of their gravity towards the centre of the earth. Hence, the waters at those places will press towards the *zenith* and *nadir*, or the points where the gravity of the waters is diminished, to restore equilibrium, and thus occasion a greater rise at those points. But in order to know the real effect of the moon on the ocean, the motion of the earth on its *axis* must be taken into account. For if it were not for this motion, the longest diameter of the watery spheroid would point directly to the moon's centre; but by reason of the motion of the whole mass of the earth on its axis, from west to east, the most elevated parts of the water no longer answer precisely to the moon, but are carried considerably to the eastward in the direction of the rotation. The waters also continue to rise after they have passed directly under the moon, though the immediate action to the moon begins there to decrease; and they do not reach their greatest height till they have got about 45° farther. After they have passed the point which is 90° distant from the point below the moon, they continue to descend, although the force which the moon adds to their gravity begins there to decrease. For still the action of the

* There are three kinds of *pewter* in common use in this country; namely, *plate*, *trifle*, and *ley*. The plate pewter is used for plates and dishes; the trifle chiefly for pint and quart pots; and the ley metal for wine measures, &c. Their specific gravities are as follows: plate, 7·248; trifle, 7·359; ley, 7·963.

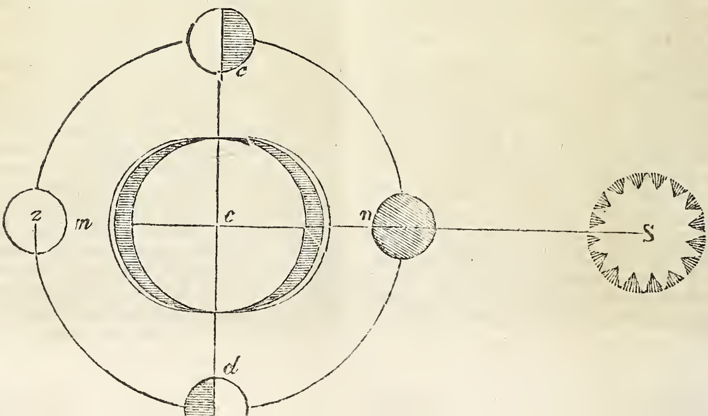
moon adds to their gravity, and makes them descend till they have got about 45° farther; the greatest elevations, therefore, do not take place at the points which are in a line with the centres of the earth and moon, but about half a quadrant to the east of these points, in the direction of the motion of rotation.

Thus it appears, if the earth were entirely covered by the ocean, as represented by the circle *b d e c* in the following figure—



that the spheroidical form which it would assume, would be so situated, that its longest diameter would point to the east of the moon, or the moon would always be to the west of the meridian of the parts of greatest elevation. And as the moon apparently shifts her position from east to west in going round the earth every day, the longer diameter of the spheroid following her motions will occasion two floods and two ebbs in the space of a lunar day, or 24 hours 48 min.

These are the effects produced by the action of the moon only; but the sun has also a considerable effect on the waters of the ocean. But it is not the action of these bodies on the earth, but the inequalities of their actions which produce these effects. The sun's action on the whole mass of the earth is much greater than of the moon's; but his distance is so great, that the diameter of the earth is a mere point compared with it; and, therefore, the difference between his effects on the nearest and farthest side of the earth, becomes on this account vastly less than it would be if the sun were as near as the moon. However, the immense bulk of the sun makes the effect still sensible, even at so vast a distance; and although the action of the moon has the greatest share in producing the tides, yet the action of the sun adds sensibly to this effect, when his action is exerted in the same direction, as at the time of *new* and *full moon*, when these two bodies are nearly in the same straight line with the centre of the earth. When this is the case, the effects of these two bodies are united, so that the tides rise higher than at any other time, and are called *spring tides;* as represented by the following figure, where S denotes the sun, *d n e z* the moon, and *c* the earth.



The action of the sun diminishes that of the moon in the *quarters*, because his action is opposed to that of the moon; consequently, the effect must be to depress the waters where the moon's action has a tendency to raise them. These tides are considerably lower than at any other time, and are called *neap tides.*

The *sring tides* do not take place on the very day of the new and full moon, nor the neap tides on the very day of the quadratures, but a day or two after; because in this case, as in some others, the effect is neither the greatest nor least when the immediate influence of the cause is greatest or least: as the greatest heat, for example, is not on the solstitial day, when the immediate action of the sun is greatest, but some time after it. And although the action of the sun and moon were to cease, yet the ocean would continue to ebb and flow for some time, as its waves continue in violent motion for some time after a storm.

The *high water* at a given place does not always answer to the same situation of the moon, but happens sometimes sooner and sometimes later than if the moon alone acted on the ocean. This proceeds from the action of the sun not conspiring with that of the moon. The different distances of the moon from the earth also occasions a sensible variation in the tides.

When the moon approaches the earth, her action in every part increases, and the difference in that action, upon which the tides depend, likewise increases. For the attraction of any body is in the inverse ratio of the square of its distance; the nearer, therefore, the moon is to the earth the greater is her attraction, and the more remote, the less. Hence, her action on the nearest parts increases more quickly than it does on the more remote parts, and therefore the tides increase in a higher proportion as the distance of the moon diminishes.

Sir Isaac Newton has shown that the tides increase as the cube of the distances decrease, so that the moon, at *half* her present distance, would produce a tide *eight times* greater. Now the moon describes an ellipse about the earth, and, of course, must be once in every revolution nearer the earth than in any other part of her orbit; consequently, she must produce a much higher tide when in this point of her orbit than in the opposite point.

This is the reason that two great *spring tides* never take place immediately after each other; for if the moon be at her least distance at the time of new moon, she must be at her greatest distance at the time of *full moon*, having performed half a revolution in the intervening time, and therefore the spring tide at the *full* will be much less than that at the preceding *change*. For the same reason, if a great spring tide happens at the time of *full moon*, the tide at the following *change* will be less.

The spring tides are highest and the neap tides lowest about the beginning of the year; for the earth being nearest the sun about the 1st of January, must be more strongly attracted by that body than at any other time of the year: hence, the spring tides which happen about that time will be greater than at any other time. And should the moon be new or full in that part of her orbit which is nearest to the earth, at the same time the tides will be considerably higher than at any other time of the year.

The tide which happens at any time, while the moon is above the horizon, is called the *superior tide*, and the other the inferior tide. When the moon is in the equinoctial, other things remaining the same, the *superior* and inferior tides are of the *same* height; but when the moon declines towards the elevated pole, the *superior* tide is higher than the *inferior*. If the latitude of the place and the declination of the moon are of contrary names, the *inferior* tide will be the highest. But the highest tide at any particular place, is when the moon's declination is equal to the latitude of the place, and of the same name; and the height of the tide diminishes, as the difference between the latitude and declination increases; therefore, the nearer any place is to that parallel whose latitude is equal to the moon's declination and of the same name, the higher will the tide be at that place.*

Such would the tides regularly be if the earth were all covered over with the ocean to a great depth; but as this is not the case, it is only at places situated on the shores of large oceans where such tides, as above described, take place.

The tides are also subject to very great irregularities from local circumstances; such as meeting with islands, shoals, headlands, passing through straits, &c. In order that they may have their full motion, the ocean in which they are produced ought to extend 90° from east to west, because that is the distance between the greatest elevation and the greatest depression produced in the waters by the moon. Hence it is, that the tides in the Pacific Ocean exceed those of the Atlantic, and that they are less in that part of the Atlantic which is within the torrid zone

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* In comparing the height of the tides at different places, it is supposed that the sun and moon are at the same distance from the earth, and in the same position with respect to the meridian of these places.

between Africa and America, than in the temperate zones, on either side of it where the ocean is much broader.

In the Baltic, the Mediterranean, and the Black seas, there are no sensible tides; for they communicate with the ocean by so narrow inlets, and are of so great extent, that they cannot speedily receive and let out water enough to raise or depress their surfaces in any sensible degree.

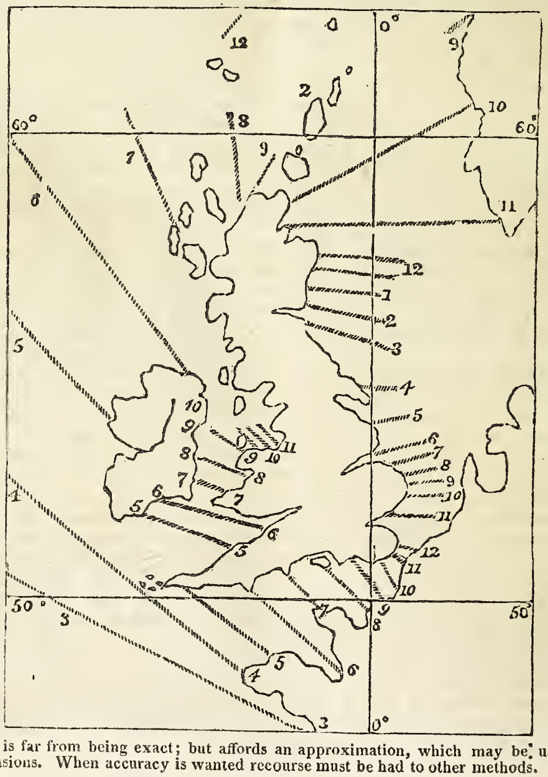
The power of the moon to raise the waters, Sir I. Newton has shown to be about $4\frac{1}{2}$ times that of the sun, and that the moon raises the waters 8 feet 7 inches, while the sun and moon together raise them $10\frac{1}{2}$ feet, when at their mean distances from the earth, and about 12 feet when the moon is at her least distance. These heights are found to agree very well with observations on the coasts of open and deep oceans, but not well on the coasts of small seas, and where the water is shallow.

The mean retardation of the tides, or of the moon's coming to the meridian in 24 hours, is $48' 45''\cdot7$, and the mean interval between two successive tides is $12^h\ 25'\ 14''\cdot2$; hence, the mean daily retardation of high water is $50'\ 28''\cdot4$.

About the time of *new* and *full* moon the interval is least, being only $12^h\ 19'\ 28''$; and at the quadratures the interval is the greatest, being $12^h\ 30'\ 7''$.

The common method of calculating the time of high water at any place, is to multiply $50'\ 28''$, or the mean daily retardation of the tides, by the moon's age, and then to divide the product by 60, which gives the mean time of the moon coming to the meridian on that day, in hours; to this is added the time of high water on the days of *full* and *change* at the given place, and the sum is the time of high water at that place on the *afternoon* of the given day, if the sum be less than 12 hours; but if greater, 12 hours 25 minutes must be subtracted, in order to have the time on the afternoon of the given day; and 25 minutes subtracted from this time will give the time of high water on the morning of the given day.*

The following figure exhibits the progress of the tides from the Atlantic through the channels surrounding the British islands; the lunar tides happening in any part of the shaded lines nearly at the hour after the moon's southing, which is indicated by the figure annexed to it.



* This method is far from being exact; but affords an approximation, which may be useful on some occasions. When accuracy is wanted recourse must be had to other methods.

OF THE FORCES WHICH RETAIN THE PLANETS IN THEIR ORBITS.

Before the time of Kepler, who flourished about the end of the 16th century, the planets were supposed to move in circular orbits; but since his great discovery of the laws which regulate the motions of these bodies, astronomers have been enabled to determine their periods, and the figure of their orbits, with the greatest exactness.

The laws of Kepler are,

1. That all the planets move round the sun, in such a manner, that the *Radius Vector*, or a line joining the sun and planet, passes over equal areas or spaces of the orbit in equal portions of time.

2. That each of the primary planets describes an ellipse, having the sun in one of its foci.

3. That the squares of the periodic times of the planets are to each other as the cubes of their mean distances from the sun.

These three laws are the basis of all physical astronomy. But in a popular work like the present, it would be improper to enter upon any demonstrations of them. However, as it may, perhaps, gratify the reader to see an illustration of the *third* law, we shall give an example, by comparing the distance and periodic time of Mercury with those of the earth.

Suppose the distance of Mercury were given, and it was required to find the time it required to perform a revolution round the sun, having the distance of the earth from the sun and the length of the year given. By the third law of Kepler it would be determined thus:—As the cube of the earth's distance (95^3 millions of miles) is to the cube of Mercury's distance ($36\frac{1}{2}^3$ millions), so is the square of the earth's periodic time ($365\frac{1}{4}^2$ days) to the square of Mercury's year (88^2 days nearly).

The distance may also be found by the same law, if the periodic time be known. Let it be required to find the distance of Mercury, having its periodic time given; then it would be determined thus: as the square of $365\frac{1}{4}$ days is to the square of 88 days, so is the cube of 95 millions of miles to the cube of $36\frac{1}{2}$ millions of miles, the distance of Mercury from the sun. In the same way, the *distance* of any other planet may be determined, if its period be known, or its period if its distance be known.*

After the laws of gravitation were known, it was demonstrated by Sir Isaac Newton, *à priori*, that the laws of Kepler must be those that regulate the system of the world.

This extraordinary man found that the laws of motion, and even the general properties of matter, are the same in the heavens as on the earth. That the elliptical figure of the orbits described both by the primary and secondary planets; the small deviations in the form and position of their orbits, as well as in the place of the planets; the facts which concern the shape, rotation, and position of their axis; and the oscillation of the waters which surround the earth, are all explained by *one principle;* namely, that of the mutual gravitation of all bodies with forces *directly* as their quantities of matter, and inversely as the squares of their distances.

But as we cannot follow this *celebrated* philosopher in all his demonstrations on this important subject, in a work of this kind, we shall endeavour to give as clear and comprehensive a view of the doctrine of gravitation, as our limits will permit, at the same time avoiding every thing abstruse.

Thus, if one body contain double the quantity of matter that another contains, its attractive power will also be double; if it contain ten times the quantity of matter, its attractive power will be ten times greater, and so on.

But if a body be placed at any distance from another body, and then removed to double the distance, it will attract it only with a fourth part of the force it did before; at three times the distance, with a ninth part of the force; and at four times the distance only with a sixteenth part, and so on.

These are termed the laws of gravitation; and are known to affect every species of matter, and to connect the most distant bodies in the universe. But what the power or principle is which causes bodies to affect each other according to these laws, we shall not attempt to enquire. Because any enquiry of this kind is not likely to be attended with much success; nor is it necessary to know the cause which produces these effects: for all that the astronomer is concerned to know is, whether such a power or force is exerted by one body on another, and if it is, what are the laws of its action. Now both of these important facts have been determined with the greatest precision, not only by calculation, but by observation and experiment.

Every person knows that a heavy body dropped from any height above the earth's surface descends in a straight line towards the centre of the earth, where the whole force of gravity seems to be accumulated. And although it be difficult to discover any sensible change in the intensity of this

* In order to perform the calculation in this example, it is necessary to be acquainted with proportion, and the method of extracting the square and cube roots.

force by a direct experiment on the weight of a body, on account of the distances to which we can either ascend or descend from the earth's surface being so small; yet the experiments which have been made with the pendulum, lead us to infer, that the force of gravity diminishes as we recede from the centre of the earth, at the rate we have stated above; namely, as the square of the distance increases. The effect of terrestrial gravity, as exhibited in descent of falling bodies, has been accurately measured, and the law which it observes fully ascertained and confirmed. It had been long known that falling bodies acquire an increase of velocity as they approach the earth; and consequently that they pass over a greater space in any given time. But Galileo was the first person who made known the law which regulates their descent, which is as follows. When a body falls freely from a state of rest, it passes through the space of sixteen feet one inch in the first second of time; and at the end of the first second it will have acquired such a degree of velocity as would carry it thirty-two feet two inches in the next second, though it should acquire no new impulse from gravity. But as the same accelerating cause continues constantly to act, it will move sixteen feet and one inch more the next second; consequently at the end of two seconds it will have fallen sixty-four feet four inches, and acquired such a velocity as would, in the next second, carry it over forty-eight feet, although it received no new impulse, and so on. If a body be projected perpendicularly upwards, its motion is continually retarded by the same cause which accelerates it in descending. But if it be projected in a direction different from the vertical line, that direction will be continually varying, and a curved line will be described in consequence of the incessant power of gravity, which, in such cases, is measured by the degree of curvature of the line described by the body.

This phenomenon affords a very good illustration of the theory of the planetary motions; for the effect produced is perfectly analogous to the motion of a planet in its orbit. Every person knows that the greater the velocity with which any body is thrown, in a horizontal direction, from an engine, the further will it range before it falls. And though a body cannot be thrown to a very great distance on the earth, yet we can conceive a body projected with such a velocity as to carry it quite *round* the earth without touching it, and to continue to circulate round it in the same path with undiminished velocity, in every respect as the moon does. By reasoning in this manner, Sir Isaac Newton conceived, that the force that produces pressure in a body that is supported, or that causes a heavy body to fall to the ground, or a body thrown obliquely in the air, to describe a curvilineal path, might perhaps be the same that retains the moon in her orbit; and makes the planets and comets revolve round the sun. Though this was at first only a plausible conjecture, yet, upon an appeal to the phenomena exhibited by these bodies, he was enabled to verify this conjecture.

It was, however, a fortunate circumstance for science, as well as for Newton, that the real motions of the heavenly bodies, as well as the laws of Kepler, were known before he undertook the investigation of this subject. For these laws were not only the basis upon which he founded his investigations, but they suggested to him the manner of conducting them.

The first law, for example, led him to the important discovery, that the action of a force always directed towards the sun *bends* the path of each planet into a curve; and the second law not only led him to the knowledge of the changes produced in the intensity of this force, by distance, but to the law which regulates the intensity.

And as it was previously known that the planets move round the sun in elliptical orbits, he was enabled to establish this important law, that the force by which a planet describes areas proportional to the times round the focus of its elliptical orbit, is inversely as the square of the distance from that focus. Hence it follows, that each planet is under the influence of a force directed towards the sun, and urging it in that direction, and that the intensity of this force is inversely proportional to the square of the planet's distance from the sun.

This power or force is sometimes called the *centripetal* force; because it urges the planet in the direction of the centre of its orbit, and prevents it from flying off in a straight line, which every body moving in a curve has a tendency to do; and that force by which it is urged in a straight line, or endeavours to fly off from the centre, is called the *centrifugal* force. It is by the nice combination of these two forces, that the whole solar system is preserved in the order in which we behold it, and that every body which forms any part of the whole, performs its revolution round the common centre of the system.

If the projectile or centrifugal force that urges the planets forward in their orbits were destroyed, each of them would fall to the sun, by the force of gravity, just as a stone descends to the earth.

The time in which the different planets would fall to the sun, from a state of rest, by the action of the centripetal force, or the power of gravity, is as follows:—Mercury, in 15 days 13 hours; Venus, 39 days 17 hours; the Earth, 64 days 13 hours; Mars, 121 days 10 hours; Jupiter, 765 days 19 hours; Saturn, 1901 days; Uranus, 5425 days; and the Moon to the earth, in 4 days 20 hours.

As the centripetal force or attractive power of the sun *increases*, as the square of the distance *decreases*, it is obvious that the nearer any body is to the sun, the more powerfully will it be attracted by him. This not only accounts for the planets which are nearest the sun moving faster in their orbits than those that are most remote from him; but also for the motion of a planet being quickest in that part of its orbit which is nearest the sun, and slowest in that part which is farthest distant from him. For the centrifugal force must always be equal to the centripetal, in order that the planet may continue to revolve in the same orbit. In this manner, all the bodies which compose the solar system are attracted by the sun, and made to perform their revolutions round him; and as *action* and *re-action* are equal, and in opposite directions, the sun is equally attracted by all the bodies that revolve round him. Hence the order and regularity of the whole system is preserved.

As neither our limits nor the nature of the present work will permit us to give a particular account of the planetary disturbances, or the effect which they have on each other, we shall conclude the present article by mentioning the discoveries which have been the result of the investigations of astronomers on this intricate subject. These may be reduced to the two following; viz. 1st. That all the inequalities produced by the mutual action of the planets are periodical; that is, after a certain time they all run through the whole series of changes to which they are subject. 2d. That amid all these changes, two of their elements remain the same—the greater axis of the orbit, and the periodic time. Hence, the mean motion of a planet, and its mean distance are constant quantities. For these important discoveries we are indebted to the celebrated French mathematicians, La Grange and La Place. And, as the late Professor Playfair has observed, they have made known to us one of the most important truths in Physical Astronomy; namely, that the system is stable; that it does not involve any principle of destruction in itself; but is calculated to endure for ever, unless the action of an external power be introduced.

Miscellaneous Subjects.

MEMOIR OF THE LIFE OF EDMUND STONE.

Edmund Stone, a distinguished self-taught mathematician, was born in Scotland; but neither the place nor time of his birth are well known; nor have we any memoirs of his life, except a letter from the Chevalier de Ramsay, author of the "Travels of Cyrus," in a letter to Father Castel, a Jesuit at Paris, and published in the "Memoirs de Trevoux," p. 109, as follows: "True genius overcomes all the disadvantages of birth, fortune, and education; of which Mr. Stone is a rare example. Born the son of a gardener of the Duke of Argyle, he arrived at eight years of age before he learned to read. By chance a servant having taught young Stone the letters of the alphabet, there needed nothing more to discover and expand his genius. He applied himself to study, and he arrived at the knowledge of the most sublime geometry and analysis without a conductor, without any other guide but pure genius.

At eighteen years of age he had made these considerable advances without being known, and without knowing himself the prodigies of his acquisition. The Duke of Argyle, who joined to his military talents a general knowledge of every science that adorns the mind of a man of his rank, walking one day in his garden, saw lying on the grass a Latin copy of Sir Isaac Newton's celebrated "Principia." He called some one to him to take and carry it back to his library. Our young gardener told him that the book belonged to him. 'To you!' replied the Duke. 'Do you understand geometry, Latin, Newton?' 'I know a little of them,' replied the young man, with an air of simplicity arising from a profound ignorance of his own knowledge and talents. The Duke was surprised; and having a taste for the sciences, he entered into conversation with the young mathematician: he asked him several questions, and was astonished at the force, the accuracy, and the candour of his answers. 'But how,' said the Duke, 'came you by the knowledge of all these things?' 'Stone replied, 'A servant taught me, ten years since, to read: does one need to know any thing more than the twenty-four letters in order to learn every thing that one wishes?' The Duke's curiosity redoubled; he sat down upon a bank, and requested a detail of all his proceedings in becoming so learned. 'I first learned to read,' said Stone: 'the masons were then at work upon your house: I went near them one day, and I saw that the architect used a rule, compasses, and that he made calculations. I enquired what might be the meaning and use of these things; and I was informed that there was a science called arithmetic: I purchased a book of arithmetic, and I learned it. I was told there was another science called geometry: I bought the books, and I learned geometry. By reading I found that there were good books on these two sciences in Latin: I bought a dictionary, and I learned Latin. I understood also that there were good books of the same kind in French: I bought a dictionary, and I learned French. And this, my Lord, is what I have done: it seems to me that we may learn every thing when we know the twenty-four letters of the alphabet.' This account charmed the Duke. He drew this wonderful genius out of his obscurity; and he provided him with an employment which left him plenty of time to apply himself to the sciences. He discovered in him also the same genius for music, for painting, for architecture, for all the sciences which depend on calculations and proportions.

"I have seen Mr. Stone. He is a man of great simplicity. He is at present sensible of his own knowledge; but he is not puffed up with it. He is possessed with a pure and disinterested love for the mathematics; though he is not solicitous to pass for a mathematician; vanity having no part in the great labour he sustains to excel in that science. He despises fortune also; and he has solicited me twenty times to request the Duke to give him less employment, which may not be worth the half of that he now has, in order to be more retired, and less taken off from his favourite studies. He discovers sometimes, by methods of his own, truths which others have discovered before him. He is charmed to find on these occasions that he is not a first inventor, and that others have made a greater progress than he thought. Far from being a plagiary, he attributes ingenious solutions, which he gives to certain problems, to the hints which he has found in others, although the connections is but very distant," &c.

Mr. Stone was author and translator of several useful works; viz. 1. "A new Mathematical Dictionary," in 1 vol. 8vo. first printed in 1726. 2. "Fluxions," in 1 vol. 8vo. 1730. The Direct Method is a translation from the French of Hospital's "Analyse des Infiniments Petis;" and the Inverse Method was supplied by Stone himself. 3. "The Elements of Euclid," in 2 vols. 8vo. 1731. A neat and useful edition of these Elements, with an account of the life and writings of Euclid, and a defence of his Elements against modern objectors. Beside other smaller works. Stone was a fellow of the Royal Society, and had inserted in the "Philosophical Transactions," (vol. xii. p. 218) an "Account of two species of Lines of the third Order, not mentioned by Sir Isaac Newton or Mr. Stirling."

SOLUTIONS OF QUESTIONS.

Quest. 64, *answered by* Mr. J. Harding.

Let C denote Charing Cross, and I the India House, and m the place of meeting; C ———— m ———— I put $a = 20$ min., $b = 45$ min., and $x =$ the minutes they travel before meeting. Then, as the distances gone over with the same uniform motion are to each other as the times in which they are described, it will be as Cm : mI :: x (the time in which John goes the distance Cm) : a (the time in which he goes over mI. And, for the same reason, as Cm : mI :: b (Peter's time in going the distance Cm) : x (the time in which he goes the distance mI.) Consequently, as x is to a in the ratio of Cm to mI, and b to x also in the same ratio, we have $x : a :: b : x$; whence $x = \sqrt{ab} = 30$. Then $30 + 20 = 50$ min. will be John's, and $30 + 45 = 75$ min. Peter's time.

This question was also solved correctly by Mr. Whitcombe, *Teacher, Lothbury*, and Mr. John Stanley, *Lambeth*, and the Proposer. We received another solution, but it was inaccurate.

Quest. 65, *answered by* Master Thomas Morris *(the Proposer)*.

	M.		Cist.		M.			
If	40	:	1	::	1	:	$\frac{1}{40}$	what the two cocks will fill of the cistern in a minute.
	50	:	1	::	1	:	$\frac{1}{50}$	
	M.		Cist.		M.			
If	100	:	3	::	1	:	$\frac{3}{100}$	what of the cistern, the two cocks will empty in a minute.
	180	:	2	::	1	:	$\frac{1}{90}$	

Then $(\frac{1}{40} + \frac{1}{50}) - (\frac{3}{100} + \frac{1}{90}) = \frac{9}{200} - \frac{37}{900} = \frac{7}{1800}$ the parts gained by the filling cocks in a minute.

Therefore, if $\frac{7}{1800}$: 1 m. :: 1 : 4 h. 17 m. $8\frac{4}{7}$ sec. the time the cistern will be filled.

This question was accurately answered by Mr. J. Harding, but his solution was too late for insertion; it was also solved by H. W. S., but the arrangement was not so clear as the above. We likewise received a solution signed Philip Minus; but it was performed according to no rule, and of course the result was erroneous.

QUESTION FOR SOLUTION.

Quest. 66, *proposed by* Mr. Whitcombe, *Teacher of Mathematics, Lothbury.*

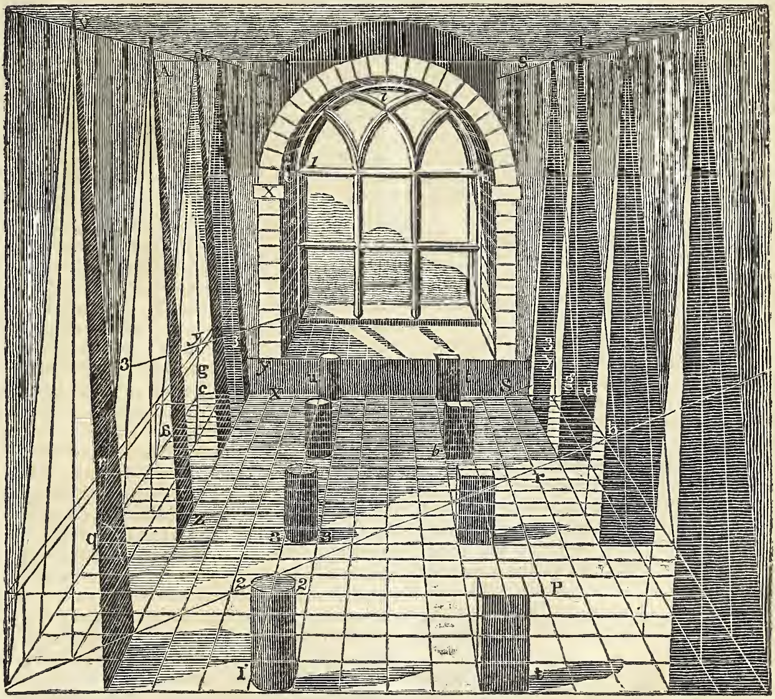
In a given semicircle to inscribe a parallelogram that shall be the greatest possible; and to give a geometrical demonstration.

PERSPECTIVE.

To put a hall into perspective, with paved floor, two ranges of pyramids, a range of cylinders, a range of square solids, of the same diameter and height with the cylinders; and let the hall be lighted from a large Gothic window in the end.

Suppose the hall to be 16 feet wide, 22 in length, and 14 feet in height.

Let A B in the following figure be the ground line, and that the parts of the figure may appear, as viewed from the different heights of the eye. Let the height of the eye, fig. 1, be 12 feet; and because the base of the room, in breadth, is less than 6 inches, the figure must be viewed under



an angle less than 60 degrees. Let the distance point be *z*, a distance greater than what the equilateral triangle on the base A B would give. Upon the ground line A B, from any scale, suppose of one fourth of an inch, set off 16 divisions, which can represent 16 feet; draw from each of these divisions to the point of sight *i*; and A *z* to the distance point, cutting the radial B *i* in *b;* draw *b a* parallel to A B; then A B *b a* is a square of 16 feet; but the length required was 22 feet. From *b*, on the right line *a b*, set off 6 feet at *b′;* draw *b′z* cutting the radial B *i* in *d;* draw *d c* parallel to A B; then A B *d c* is the dimensions, 16 feet by 22, as was required. Through the points where the distance lines *b′z*, A *z*, cuts the several radials, draw right lines parallel to A B; then the whole floor will be divided into 352 square feet, which may represent the pavement. To find the height of the roof, draw A K perpendicular to A B, at the height of 14 feet, through K draw K L equal and parallel to A B; draw the radials K *i*, L *i;* from the points *d*, *c*, in the right line *d c*, draw the perpendiculars *c k*, *d l*, cutting the radials K *i*, L *i*, in the points *k*, *l;* join *k l*, then A K *k c* is one side of the room, equal to its opposite side B L *l c;* A B *d c* is the floor, K L *l k* is the roof, and *k c d l* is the end of the room fronting the observer.

2. To raise the pyramids. Let the base be two feet square, and 5 feet distance; from the centre of the base, draw a line at right angles to the ground line, and of length equal to the height of the roof; and draw right lines from each angle of the pyramid to the vertex.

To ascertain the point in which this vertex shall touch the roof. Observe, that the centre of the pyramid is one foot from the ground line A B, and one foot from A *i*, the ground line of the perpendicular plane, which forms the side of the wall, therefore from the point K, upon the line K L, set off K *o*, equal to one foot; draw the radial *o i*, and distance line *o z*, cutting the radial *o i* in *v;* then *v* is the point of the roof which the vertex of the pyramid touches; and the radial *o v i*, regulates the height and position of the whole range. In the same manner, the vetex on the other side may be found. Or, from L set off L *o* equal to K *o;* draw the radial *o i* through *v;* draw *v..v* parallel to K L, cutting *o i* in *v′;* then *v* is the place of the vertex of the pyramid in the roof, and the radial *o i* regulates the whole range on that side. The distance the pyramids are placed from one another, is at pleasure; in this example the distance is taken 5 feet. N.B. The side of pyramids of the left hand, ought to have been light, as those on the right hand are.

3. To draw the range of cylinders. Let the diameter of each be 1 foot, the height 2 feet, the distance from the base of the pyramid 3 feet, and their distance from one another 8 feet.

To regulate the height of the cylinder. Upon the perpendicular A K set off A P equal to 2 feet; draw the radials P *i*, which regulates all objects of that height, from the station of the observer, to the point of sight.

From P draw the indefinite right line P *p* parallel to the ground line A B; at the points 1, 1, of the perspective square, draw the right lines 1 .2, perpendicular to the ground line, and cutting the indefinite right line P *p* in .2 2; in the perspective squares at 1·1, 2, 2, inscribe the perspective circles, by prob. 12, and join their diameters, which gives the cylinder required.

To find the height of the second cylinder in the range, whose base is the side of the square 3..3; produce 3.3 to the radial A *i*, cutting it in *q;* draw *q r* parallel to A P, cutting the radial P *i* in *r;* through *r* draw the indefinite right line *rr* parallel to A B; from 3.3, draw right lines perpendicular to the ground line, to the height of *r r;* form the square, inscribe the circle, and join the diameters, as in the last. In the same manner, from each of the bases of the remaining cylinders in the range; produce their bases to the radials A *i;* draw lines parallel to A *p*, where these cut the parallel P *i*, draw lines parallel to the ground line, gives the respective heights of 2 feet.

After the above description, an inspection of the square figures will be sufficient, as the squares are described in the same manner as those in which the cylinder were inscribed; and their heights are obtained in the same manner.

4. To form the Gothic window in a front view, 7 feet by 12, for the opening of the light, with a circular arch above, width of the inside of the window 10 feet, the lower lintel of the window 2 feet above the floor. Let the thickness of the wall, from the inside to the frame of the window, be 3 feet, and from thence to the outside of the wall be 1 foot. Set off 3 feet for the thickness of the wall to the inside of the frame, in the same manner as the floor was extended. If it is to be open from the floor upwards, upon the ground line *c d* set off *d s* equal to 3 feet, or B S upon the ground line; draw the radial S *i* cutting *d c* in *s;* draw *s z* cutting the radial *d i* in *g;* draw *g g* parallel to *d c*. And because the window is to be 10 feet wide within, set off the distance of the inner corner of the window from B, upon the ground line, which, in this example, is 3 feet at S; but if more or less, another letter and distance must be taken; and the window being 7 feet wide at the glass frame, measure off $1\frac{1}{2}$ from S to *t*, and 7 feet from *t* to *l*, and $1\frac{1}{2}$ feet from *l* to *x;* draw the radial *t i* cutting the line *g g* in *t; l i* cutting *g g* in *u; x i* cutting *g g* in *x;* join *s t*, *x u*. Draw the right lines *s s*, *t h*, *u u*, *x x*, perpendicular to the ground line, and extending to the height of the impost, which cannot in this figure exceed 7 or 8 feet, as the height of the room is only 14 feet.

But if below the window is to be solid wall to the height of 2 feet from the floor, draw *c y* parallel to A P, cutting the radial P *i* in *y;* draw *y y* parallel to *c d;* from the point in which *y y* cuts the radial *s i*, draw to the distance point, cutting the radial B *i* in 3; draw the right line 3··3 parallel to *y y;* then the right line 3··3 gives the lower part of the frame of the window on the inside; and being below the eye, the sole of the window without will likewise be in view.

The height of the room being only 14 feet, the height of the spring of the arch cannot exceed 8 feet; but to allow greater scope for the arch stone, part of the roof is formed a cove.

At the height of the impost, which is, by the rules of architecture, one eighth part of the opening, and its projection from one third to four ninths of its height, according to the order to which it belongs. With a radius of 5 feet describe a semicircle, meeting the impost in *x..s;* and with a radius of 6 feet for the architrave, describe the outer semicircle. Let this arch be divided as in the figure, and the radii of the architrave directed to the centre of the semicircle. With the radius of $3\frac{1}{2}$ feet, describe the inner semicircle, meeting the impost in *u..h*. Form the inner part of the window, by drawing radials from each of the divisions, on the corner of the architrave, to the point of sight, both in the plain and arched part of the window.

The window being a front view, the panes are at equal distances, and are formed by dividing the base according to the number of panes intended; the different heights are measured off upon the perpendicular A K, from the scale as laid down upon the ground line. The form of the bars are regulated, as to their rise above the glass, or the depth of the glass below them, in the same manner as the depth of the window; but being here so small, they may be formed by the hand, and regulated by the eye of the artist.

The Gothic arches are described according to the number of the panes they contain, with a radius of $3\frac{1}{2}$ feet from the centre 1, 2, &c. on each side.

Observe.—That the height being taken off, upon the perpendicular A K, from the same scale upon which the other parts of the figure were measured; A P, in this example, is 2 feet, and any line bounded by the radials A *i*, P *i*, drawn parallel to A P, is of the same measure with A P. Therefore, to obtain the height of any object, that stands upon the plane A B *d c*, and from *d c* continued to the point of sight: as, the object standing upon 3··3, the line 3..*q* drawn from the base 3··3 to *q*, in the radial A *i*; and from the point of section *q*, the right line *q r*, be drawn perpendicular to the ground line, cutting P *i* in *r*; then *r q* is the height of the object at that distance from the ground line. In the same manner *c y* is the given height at its distance from the ground line, or from the point of sight.

And, if the object is nearer the observer than the ground line A B, the radials, A *i*, P *i*, being produced, then the line drawn through the base of the object parallel to the ground line, till it cut A *i*; the perpendicular raised from that point in which it cuts the radial P *i*, is the height of the object; which will be greater than A P, and the object will appear of greater magnitude than if placed upon A B, in the reciprocal proportion of its distance from the observer; or, in the direct proportion of its distance from the point of sight.

For, because the triangles A *i* P, *q i r*, *c i y*, have their sides *q r*, and *c y*, each parallel to A P; and have the angle at *i* common, the triangles are similar; and the perpendiculars A P, *q r*, *c y*, are to one another in the direct proportion of the side *i c*, *i q*, and *d i*, their respective distances from *i*; or, in the reciprocal proportion of their several distances from the station of the observer; and the same proportions will hold, if the object is nearer to the observer than the ground line A B.

OF MAGNETISM.

The theory of magnetism, bearing a strong resemblance to that of electricity, naturally falls to be considered after it. We shall, therefore, devote a few pages to the consideration of this interesting subject, having now finished that of electricity.

We have seen that the electric fluid not only exerts attractions and repulsions, and causes a peculiar distribution of neighbouring portions of a fluid similar to itself, but we have also seen it excited in one body and transferred to another, in such a manner as to be perceptible to the senses, or at least to cause sensible effects in its passage. The attraction and repulsion, and the peculiar distribution of the neighbouring fluid, are found in the phenomena of magnetism; but we do not perceive that there is ever any actual excitation, or any perceptible transfer of the magnetic fluid from one body to another distinct body; and it has also this striking peculiarity, that metallic iron is very nearly, if not absolutely, the only substance capable of exhibiting any indications of its presence or activity.

In order to explain the phenomena of magnetism, the particles of a fluid are supposed to repel each other, and to attract the particles of metallic iron with equal forces, diminishing as the square of the distance increases; and the particles of such iron must also be imagined to repel each other in a similar manner. Iron and steel, when soft, are conductors of the magnetic fluid, and become less and less pervious to it as their hardness increases.

A strong degree of heat appears from the experiments of Gilbert and of Mr. Cavallo, to destroy completely all magnetic action.

It is perfectly certain that magnetic effects are produced by quantities of iron incapable of being detected, either by their weight or by any chemical tests. Mr. Cavello found that a few particles of steel, adhering to a hone on which the point of a needle was slightly rubbed, imparted to it magnetic properties; and Mr. Coulomb has observed, "that there are scarcely any bodies in nature which do not exhibit some marks of being subjected to the influence of magnetism, although its force is always proportional to the quantity of iron which they contain, as far as that quantity can be ascertained: a single grain being sufficient to make 20 pounds of another metal sensibly magnetic. A combination with a large portion of oxygen, deprives iron of the whole or the greater part of its magnetic properties; finery cinder is still considerably magnetic, but the more perfect oxides and the salts of iron only in a slight degree; it is also said that antimony renders iron incapable of being attracted by the magnet. Nickel, when freed from arsenic and from cobalt, is decidedly magnetic, and the more so as it contains less iron.

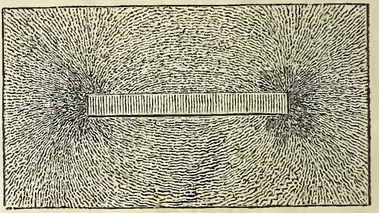
The *aurora borealis* is certainly in some measure a magnetical phenomenon; and if iron were the only substance capable of exhibiting magnetic effects, it would follow that some ferruginous particles must exist in the upper regions of the atmosphere. The light usually attending this magnetic meteor may possibly be derived from electricity, which may be the immediate cause of a change of the distribution of the magnetic fluid contained in the ferruginous vapours, that are imagined to float in the air.

We are still less capable of distinguishing with certainty in magnetism than in electricity, a positive from a negative state, or a real redundancy of the fluid from a deficiency. The north pole of a magnet may be considered as the part in which the magnetic fluid is either redundant or deficient, provided that the south pole be understood in a contrary sense: thus, if the north pole of a magnet be supposed to be positively charged, the south pole must be imagined to be negative; and in hard iron or steel, these poles may be considered as unchangeable.

A north pole, therefore, always repels a north pole, and attracts a south pole. And in a neutral piece of soft iron, near to the north pole of a magnet, the fluid becomes so distributed by induction, as to form a temporary south pole next to the magnet, and the whole piece is of course attracted, from the greater proximity of the attracting pole. If the bar is sufficiently soft, and not too long, the remoter end becomes a north pole, and the whole bar a perfect temporary magnet. But when the bar is of hard steel, the state of induction is imperfect, from the resistance opposed to the motion of the fluid; hence the attraction is less powerful, and an opposite pole is formed, at a certain distance, within the bar; and beyond this another pole, similar to the first, the alternation being sometimes repeated more than once.

The polarity of magnets, or their disposition to assume a certain direction, is of still greater importance than their attractive power. If a small magnet, or simply a soft wire, be poised on a centre, it will arrange itself in such a direction, as will produce an equilibrium of the attractions and repulsions of the poles of a larger magnet; being a tangent to a certain oval figure passing through those poles, of which the properties have been calculated by various mathematicians.

The same effect is observable in iron filings placed near a magnet, and they adhere to each other in curved lines, by virtue of their induced magnetism, the north pole of each particle being attached to the south pole of the particle next it. This arrangement is represented by the following figure, and may be actually produced,



by placing the filings either on mercury, or on any surface that can be agitated; it may also be imitated by strewing powder on a plate of glass, supported by two balls, which are contrarily electrified.

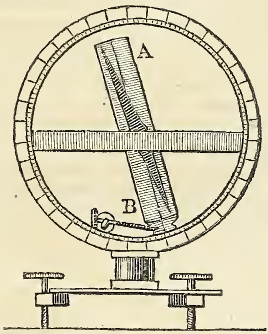
The polarity of a needle may often be observed, when it exhibits no sensible attraction or repulsion as a whole; and this may easily be understood by considering, that when one end of a needle is repelled from a given point, and the other is attracted towards it, the two forces, if equal, will tend to turn it round its centre, but will wholly destroy each other's effects, with respect to any progressive motion of the whole needle. Thus, when the end of a magnet is placed under a surface on which iron filings are spread, and the surface is shaken, so as to leave the particles for a moment in the air, they are not drawn sensibly towards the magnet, but their ends, which are nearest to the point over the magnet, are turned a little downwards, so that they strike the paper further and further from the magnet, and then fall outwards, as if they were repelled by it.

The magnets, which we have hitherto considered, are such as have a simple and well determined form; but the great *compound magnet*, which directs the mariner's compass, and which appears to consist principally of the metallic and slightly oxidized iron, contained in the internal parts of the earth, is probably of a far more intricate structure, and we can only judge of its nature, from the various phenomena derived from its influence.

The accumulation and the deficiency of the magnetic fluid, which determine the place of the poles of this magnet, are probably in fact considerably diffused, but they may generally be imagined, without much error in the result, to centre in two points, one of them nearer to the north pole of the earth, the other to the south pole. In consequence of their attractions and repulsions, a needle, whether previously magnetic or not, assumes always, if freely poised, the direction necessary for its equilibrium; which, in various parts of the globe, is variously inclined to the meridian and to the horizon. Hence arises the use of the compass in navigation and surveying; for a needle (which is poised with the liberty of a horizontal motion) always assumes the direction of the magnetic meridian, which, for a certain time, remains almost invariable for the same place; and as the true meridian can easily be determined, the *variation* is thus ascertained.

Though the dipping needle is only moveable in a vertical plane, yet it evinces a similar property to that of the horizontal needle; for when the vertical plane in which it is at liberty to move, is placed in the magnetic meridian, the needle acquires an inclination to the horizon, which varies according to the place with respect to the magnetic poles. The dip of the north pole of the needle in the neighbourhood of London, is at present about 72 degrees.

The following figure represents the dipping needle.



The piece A B is brought into such a situation, that the line drawn on it coincides with the middle of the vibrations of the needle. The position of the needle may be changed, either by turning the stand half round, or by turning the needle within the stand.

A bar of soft iron, placed in the situation of the dipping needle, acquires from the earth a temporary state of magnetism, which may be reversed at pleasure by reversing its direction; but bars of iron, which have remained long in or near this direction, assume a permanent polarity; for iron, even when it has been at first quite soft, becomes in time a little harder. A natural magnet, or loadstone, is no more than a heavy iron ore, which, in the course of ages, has acquired a strong polarity from the great primitive magnet. It must have lain in some degree detached, and must possess but little conducting power, in order to have received and to retain its magnetism.

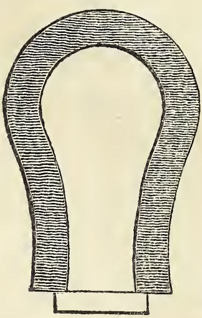
We cannot, from any assumed situation of two or more magnetic poles, calculate the true position of the needle for all places; and even in the same place, its direction is observed to change in the course of years, according to a law which has never yet been generally determined, although the variation which has been observed at any one place, since the discovery of the compass, may perhaps be comprehended in some very intricate expressions; but the less dependence can be placed on any calculations of this kind, as there is reason to think that the change depends rather on a chemical than on physical causes. Dr. Halley, indeed, conjectured, that the earth contained a nucleus, or seperate sphere, revolving freely within it, or rather floating in a fluid contained in the intermediate space, and causing the variation of the magnetic meridian; and others have attributed the effect to the motions of the celestial bodies: but in either case, the changes produced would have been much more regular and universal than those which have been actually observed. Temporary changes of the terrestrial magnetism, have certainly been sometimes occasioned by other causes; such causes are, therefore, most likely to be concerned in the more permanent effects. Thus, the eruption of Mount Hecla was found to derange the position of the needle considerably; the aurora borealis has been observed to cause its north pole to move six or seven degrees to the westward of its usual position; and a still more remarkable change occurs continually in the diurnal variation.

The line of no variation passed in 1657 through London, and in 1666 through Paris: its northern extremity appears to have moved continually eastwards, and its southern parts westwards: and it now passes through the middle of Asia. The opposite portion seems to have moved more uniformly westwards; it now runs from North America to the middle of the South Atlantic. On the European side of these lines, the declination is westerly; on the South American side, it is easterly. The variation in London has been for several years a little more than 25°. In the West Indies it changes but slowly; for instance, it was 5° near the island of Barbadoes, from 1700 to 1756.

The art of making magnets consists in a proper application of the attractions and repulsions of the magnetic fluid, by means of the different conducting powers of different kinds of iron and steel, to the production and preservation of such a distribution of the fluid in a magnet, as is the best fitted to the exhibition of its peculiar properties.

We may begin with any bar of iron that

has long stood in a vertical position; but it is more common to employ an artificial magnet of greater strength. When one pole of such a magnet touches the end of a bar of hard iron or steel; that end assumes, in some degree, the opposite character, and the opposite end the same character: but in drawing the pole along the bar, the first end becomes neutral, and afterwards has the opposite polarity; while the second end has its force at first a little increased, then becomes neutral, and afterwards is opposite to what it first was. When the operation is repeated, the effect is at first in some measure destroyed, and it is difficult to understand why the repetition adds materially to the inequality of the distribution of the fluid; but the fact is certain, and the strength of the new magnet is for some time increased at each stroke, until it has acquired all that it is capable of receiving. Several magnets, made in this manner, may be placed side by side, and each of them being nearly equal in strength to the first, the whole collection will produce together a much stronger effect; and in this manner we may obtain from a weak magnet others continually stronger, until we arrive at the greatest degree of polarity, of which the metal is capable. It is, however, more usual to employ the process called the double touch: placing two magnets, with their opposite poles near to each other, or the opposite poles of a single magnet, bent in the following form,



with the middle of the bar: the opposite actions of these poles then conspire in their effort to displace the magnetic fluid, and the magnets having been drawn backwards and forwards repeatedly, in equal number of times to and from each end of the bar, with a considerable pressure, they are at last withdrawn in the middle, in order to keep the poles at equal distances.

CHEMISTRY.

OF NICKEL.

Hierne was the first person who mentioned the particular ore which contains nickel, in a work on the art of discovering metals, published in 1694. The ore was named kupfernickel by the Germans, which signifies false copper. Henckel considered it as a species of cobalt, or arsenic mixed with copper. Cramer referred it also to the copper and arsenical ores, though he did not obtain copper from it; which is also confessed by Henckel.

In its highest state of purity, it is of a yellowish or reddish white, of variable brilliancy and granulated texture. This texture is lamellated only in the case of impurity.

Its specific gravity, according to Richter, after being melted, is 8·279; but when hammered, it becomes 8·666.

It is malleable both cold and hot; and may without difficulty be hammered out into plates not exceeding the hundredth part of an inch in thickness.

It is attracted by the magnet at least as strongly as iron. Like that metal, it may be converted into a magnet; and in that state points to the north, when freely suspended, in the same manner as a common magnetic needle.

There are three ores of nickel, very distinct and very easy to be distinguished; these are the sulphuret of nickel, ferruginous nickel, and native oxide of nickel.

Rinman also affirms, that nickel has been found a native of Hesse; it is heavy, of a deep red, forming a kind of product of the furnaces among the materials from which nickel may extracted. It is considered as an alloy of cobalt and bismuth, by the medium of nickel.

Nickel is very difficult to be oxidized by the action of caloric and of the air. When it is heated under a muffle, and constantly agitated, it only assumes a dark colour. However, by long exposure to moist and cold air, it becomes covered with an efflorescence of a clear green colour, of a very particular and distinct tinge. It is this efflorescence which is found upon the surface of the sulphurous ores of nickel, the tinge of which being very remarkable and very different from that of copper, enables us to distinguish them with ease and certainty.

The alloys of this metal are but very imperfectly known.

Mr. Hatchett melted a mixture of 11 parts gold and one nickel, and obtained an alloy of the colour of fine brass. It was brittle, and broke with a coarse-grained earthy fracture. The specific gravity of the gold was 19·172; of the nickel 7·8; that of the alloy 17·068. The bulk of the metals before fusion was 2792, after fusion 2812; hence they suffered an expansion. Had their bulk before fusion been 1000, after fusion it would have become 1007. When the proportion of nickel is diminished, and copper substituted for it, the brittleness of the alloy gradually diminishes, and its colour approaches to that of gold. The expansion, as was to be expected, increases with the proportion of copper introduced.

Nickel has hitherto been applied to little or no use. It cannot, however, be doubted that it may be employed with great advantage in the manufacture of enamels, glass, porcelain, and pottery. It is even probable that it may be an ingredient in the secret processes of some manufactures, as large portions of it are frequently found with the druggests of Paris, who procure it from Saxony only in proportion to the demand which is made for it.

OF CADMIUM.

Cadmium was first discovered by M. Stromeyer, in the autumn of 1817, in carbonate of zinc, which he was examining in Hanover. It has been since found in the Derbyshire silicates of zinc.

The following is Dr. Wollaston's process of procuring cadmium. From the solution of the salt of zinc supposed to contain cadmium, precipitate all the other metallic impurities by iron; filter, and immerse a cylinder of zinc into the clear solution. If cadmium be present it will be thrown down in the metallic state, and when redissolved in muriatic acid, will exhibit its peculiar character on the application of the proper tests.

The colour of cadmium is a fine white, with a slight shade of blueish-grey, approaching much to that of tin, which it resembles in lustre and susceptibility of polish. Its texture is compact, and its fracture hackly. It crystallizes easily in octahedrons, and presents on its surface, when cooling, the appearance of leaves of fern. It is flexible, and yields readily to the knife. It is harder and more tenacious than tin; and, like it, stains paper, or the fingers. It is ductile and malleable, but when long hammered, it scales off in different places. Its specific gravity, before hammering, is 8·6, and when hammered, it is 8·69. It melts, and is volatilized under a red heat. Its vapour, which has no smell, may be condensed in drops like mercury, which, on congealing, present distinct traces of crystallization.

Cadmium is as little altered by exposure to the air as tin. When heated in the open air, it burns like that metal, passing into a smoke which falls and forms a very fixed oxide, of a brownish-yellow colour. Nitric acid readily dissolves it cold; dilute sulphuric, muriatic, and even acetic acids act feebly on it with the disengagement of hydrogen. The solutions are colourless, and are not precipitated by water.

Cadmium unites easily with most of the metals, when heated along with them and the air excluded; but most of its alloys are brittle and without colour. That of copper and cadmium is white, with a slight tinge of yellow. Its texture is composed of very fine plates. A very small portion of cadmium communicates a good deal of brittleness to copper; but at a strong heat cadmium flies off.

Cadmium unites with several other metals; particularly with cobalt, platinum, and mercury. With the last metal it forms an amalgam, the specific gravity of which exceeds that of mercury itself.

OF ZINC.

It is believed that zinc was not known to the ancients. Paracelsus is the first Chemist who has treated of it, and who gave it the name which it bears. Agricola has since termed it *contre-feyne*, and Boyle *speltrum*. Albertus Magnus, who died in the year 1280, makes very distinct mention of it; he knew that it was combustible and inflammable, and that it coloured metals. It appears that zinc has for a long period back been extracted from its ores in the East Indies, as was first discovered by Jungius, in the year 1647. It was brought from those parts under the name of *tutenague*. Without being particularly acquainted with it, and distinguishing it accurately from other metals, the Greeks seem also to have employed it, as it is said to have constituted a part of the famous Corinthian brass.

It is not known by what process the Chinese obtain this metal, which they employ in a great number of alloys; it is, however, believed that they extract it by distillation. Henckel asserted, in 1721, in his Pyritologia, that zinc might be extracted from calamine.

Zinc is of a brilliant white colour, with a shade of blue, and is composed of a number of thin plates adhering together. When this metal is rubbed for some time between the fingers, they acquire a peculiar taste, and emit a very perceptible smell.

When rubbed upon the fingers, it tinges them of a black colour. The specific gravity of melted zinc varies from 6·861 to 7·1; the lightest being esteemed the purest. When hammered it becomes as high as 7·1908.

This metal forms, as it were, the limit between the brittle and the malleable metals. When struck with a hammer it does not break, but yields, and becomes somewhat flatter; and by a cautious and equal pressure, it may be reduced to pretty thin plates, which are supple and elastic, but cannot be folded without breaking. This property of zinc was first ascertained by Mr. Sage. When heated somewhat above 212°, it becomes very malleable. It may be beat at pleasure without breaking, and hammered out into thin plates. When carefully annealed, it may be passed through rollers. It may also be very readily turned on the lathe. When heated to about 400°, it becomes so brittle, that it may be reduced to powder in a mortar.

It possesses a certain degree of ductility, and may with care be drawn out into wire. Its tenacity, from the experiments of Muschenbroeck, is such, that a wire, whose diameter is equal to $\frac{1}{10}$th of an inch, is capable of supporting a weight of about 26 lbs.

When heated to the temperature of about 680°, it melts; and if the heat be increased, it evaporates, and may be easily distilled over in close vessels. When allowed to cool slowly, it crystallizes in small bundles of quadrangular prisms, disposed in all directions. If they are exposed to the air while hot, they assume a blue changeable colour.

Zinc is applied to uses no less numerous than important in many of the arts. It forms a part of a number of hard and white alloys. It is particularly employed in the fabrication of tombac and brass. The eastern nations, and especially the Chinese, make use of it, as has already been observed, much more frequently than the Europeans; perhaps because they possess it in greater abundance than we do, and perhaps because they are better acquainted with its useful properties.

Zinc and its chemical preparations have already been applied to medicinal purposes. Its property of conducting so great a degree of galvanism, may hereafter render it much more valuable to the healing art.

OF BISMUTH.

Bismuth is of a reddish white colour, and almost destitute both of taste and smell. It is composed of broad brilliant plates adhering to each other. The figure of its particles, according to Haüy, is an octahedron, or two four-sided pyramids, applied base to base.

Its specific gravity is 9·822; but when hammered cautiously, its density, as Muschenbroeck ascertained, is considerably increased. It is not therefore very brittle; it breaks however, when struck smartly by a hammer, and consequently is not malleable. Neither can it be drawn out into wire. Its tenacity, from the trials of Muschenbroeck, appears to be such, that a rod one-tenth of an inch in diameter, is capable of sustaining a weight of nearly 29 lbs.

When heated to the temperature of 476°, it melts; and if the heat be much increased, it evaporates, and may be distilled over in close vessels. When allowed to cool slowly, and when the liquid metal is withdrawn as soon as the surface congeals, it crystallizes in parallelopipeds, which cross each other at right angles.

When exposed to the air, it soon loses its lustre, but scarcely undergoes any other change. It is not altered when kept under water.

Bismuth is alloyed with several metals, in order to give them hardness, rigidity, or consistence; it is particularly useful to the pewterers, and all those who employ white and hard alloys. It is generally believed that it acts upon the animal economy in the same manner as lead, though this opinion is yet supported by no decisive facts.

The utility of its oxides is very considerable. It is employed in this form by the manufacturers of porcelain in the preparation of some yellow enamels; it is mixed with other oxides, in order to tinge the colour of glazes and paintings. It is sometimes used in the manufacture of coloured glass, and to give a yellow tinge approaching to green. The white paint or focus made from the oxide of bismuth is often used by females to paint the face; but it injures the skin very much, and is converted to a black by sulphuretted hydrogen gas.

OF ANTIMONY.

Antimony is of a greyish white colour, and has a good deal of brilliancy. Its texture is laminated, and exhibits plates crossing each other in every direction, and sometimes assuming the appearance of imperfect crystals. Haüy has with great labour ascertained, that the primitive form of these crystals is an octahedron, and that the integrant particles of antimony have the figure of tetrahedrons.

When rubbed upon the fingers, it communicates to them a peculiar taste and smell.

Its specific gravity is, according to Brisson, 6·702; according to Bergman, 6·86. Hatchett found it 6·712.

It is very brittle, and may be easily reduced in a mortar to a fine powder. Its tenacity, from the experiments of Muschenbroeck, appears to be such, that a rod of $\frac{1}{10}$th of an inch in diameter is capable of supporting about 10 pounds weight.

When heated to 810° Fahrenheit, or just to redness, it melts. If after this the heat be increased, the metal evaporates.

Antimony is the base of the alloy which

is employed for casting printing-types, to which it communicates hardness. It is often made to enter, with lead and tin, into rigid hard alloys, which are very useful for a variety of purposes. The oxide of antimony is used in the fabrication of coloured glass, enamels, the glazing and painting upon porcelain; it is the basis of the yellow, brownish, and orange colours, which resemble the amethyst. It is mixed with several other oxides, in order to produce a great variety of colours, the effects of which have been observed, but their causes have not yet been explained.

OF MANGANESE.

Manganese is distinguished from all other metals by the following properties. It is of a brilliant whiteness approaching to grey, which is quickly altered in the air; its texture is granulated, without being so fine and close as that of cobalt; its fracture is rough and unequal: its specific gravity is 6·850; it holds, together with iron, the first rank in the order of hardness; it is one of the most brittle metals; at the same time it is one of the most difficult to be fused. Guyton places it immediately after platina, and determines it at the 160th degree of Wedgwood's pyrometer. We know neither its dilatability by caloric, nor its conducting property. It is frequently susceptible of being attracted by the load-stone, especially when it is in the state of powder, on account of the iron which it contains, and which is almost as difficult to be separated from it as from nickel; it has no perceptible smell nor taste; in communication with other metals, it exerts the galvanic action upon the nervous and muscular systems of animals; its colour is extremely variable.

Only one ore of manganese is as yet well known; namely, its native oxide, which some modern mineralogists, amongst others Mr. Kirwan, announced as being combined with carbonic acid. This oxide is frequently mixed with iron, barytes, silex, lime, &c.; it varies also by its state of oxidation, or by the proportion of oxygen which it contains.

The ores of manganese are not worked in the large way, not merely on account of the refractory nature of these ores, but more especially because it is of no utility in its metallic state. The places where the native oxide of manganese is found are merely worked, in order to furnish the manufactories of glass, bleaching, &c. with this oxide, which is employed in them.

OF COBALT.

The ores of cobalt have been used in different parts of Europe since the beginning of the sixteenth century, to tinge glass of a blue colour. But the nature of cobalt was altogether unknown till it was examined by Brandt in 1733. This celebrated Swedish Chemist obtained from it a new metal, to which he gave the name of cobalt. Lehmann published a very full account of every thing relating to this metal in 1761.

Cobalt is of a grey colour, with a shade of red, and by no means brilliant. Its texture varies according to the heat employed in fusing it. Sometimes it is composed of plates, sometimes of grains, and sometimes of small fibres adhering to each other. It has scarcely any taste or smell.

Its specific gravity, according to Bargman and the School of Mines at Paris, is 7·7. Mr. Hatchett found a specimen 7·645.

It is brittle, and easily reduced to powder; but if we believe Leonhardi, it is somewhat malleable when red hot. Its tenacity is unknown.

When heated to the temperature of 130° Wedgewood, it melts; but no heat which we can produce is sufficient to cause it to evaporate. When cooled slowly in a crucible, if the vessel be inclined the moment the surface of the metal congeals, it may be obtained crystallized in irregular prisms.

Like iron, it is attracted by the magnet; and, from the experiments of Wenzel, it appears that it may be converted into a magnet precisely similar in its properties to the common magnetic needle.

Cobalt is not used in its metallic form; but it is much employed to make blue glasses or enamels. In the manufactories of porcelain, much care is taken to have the oxides of cobalt very pure and attenuated. The grey ore is chosen well crystallized; this is roasted, and treated with the nitric or muriatic acid, or otherwise it is burned with nitrate of potash; the oxide is carefully washed with much water; by which treatment the oxide is obtained in violet coloured powder, very fine and very homogeneous, which affords the purest and most beautiful blue when treated with a vitreous flux. The elegant blue of the porcelain of Sevres is of this nature.

OF TELLURIUM.

In the year 1797, Mr. Klaproth, of Berlin, discovered a brittle whitish metal among the ores of gold, brought from the mountains of Transylvania, to which he gave the name of *Tellurium.*

Pure tellurium is of a tin-white colour, verging to lead-grey, with a high metallic lustre; of a foliated fracture, and very brittle, so as to be easily pulverized. Its specific gravity is 6·115; it melts before ignition, requiring a little higher heat than lead, and less than antimony; and, according to Gmelin, is as volatile as arsenic. When cooled without agitation, its surface has a crystallized appearance. Before the blow-pipe on charcoal, it burns with a vivid blue light, greenish on the edges, and is dissipated in greyish white vapours of a pungent smell, which condense into a white oxide. This oxide, heated on charcoal, is reduced with a kind of explosion, and soon again volatilized. Heated in a glass retort, it fuses into a straw-coloured striated mass. It appears to contain about 16 per cent. of oxygen.

Nothing decisive can yet be said concerning the uses of this metal, on account of its scarcity, and its recent discovery. But should it be found in other ores, as well as in those of Transylvania, it may become of great utility in the arts, as appears from its extreme fusibility, and its slight adhesion to oxygen.

OF ARSENIC.

From the earliest period in which mankind worked the metallic ores, they must have ascertained the volatility, the odour, and the noxious effects of arsenic. Nevertheless, it remained unknown as a metal, and was not placed among the semi-metals, or brittle metallic bodies, till the beginning of the eighteenth century; when Paracelsus announced, that it might be obtained white in the metallic form. Schroder, in 1649, mentioned a metal extracted from orpiment and arsenic; and Lemery, in 1675, described a process, which is at present used with success in the mixture of fixed alkali and soap with this oxide, to obtain what is called the regulus. The ancients were acquainted with its oxide, its yellow and red sulphuret, under the name of arsenic, sandarach, and orpiment. Mineralogists were, for a long time, content to range it among sulphurous matters, and considered it only as a mineralizer of the metals. Brandt, in 1733, and Macquer, in 1746, showed that it is a true metal, possessing properties highly characteristic, and different from those of every other metal.

Arsenic has a blueish white colour not unlike that of steel, and a good deal of brilliancy. It has no sensible smell while cold; but when heated, it emits a strong odour of garlic, which is verycharacteristic.

Its specific gravity is 8·31.

It is perhaps the most brittle of all the metals, falling to pieces under a very moderate blow of a hammer, and admitting of being easily reduced to a very fine powder in a mortar.

Its fusing point is not known, because it is the most volatile of the metals, subliming without melting when exposed in close vessels to a heat of 356°.

Arsenic, in the metallic form, is but little employed, except in chemical laboratories, where various experiments, researches, and demonstrations are carried on.

As it is sometimes employed for killing flies, great caution should be used in applying it to this purpose; for this substance, which is sold under the name of testaceous cobalt, or fly-powder, is very dangerous to animals of every description.

In some manufactories it is alloyed with various metals, in order to whiten and harden them; the white copper is frequently an alloy of this kind. But though such alloys may be of use in some cases, they ought never to be employed for the preparation of food, drinks, or medicines.

OF CHROMIUM.

The analysis of a mineral made by other means, and with more care than hitherto had been applied to its examination, presented in December, 1797, to Vauquelin, the discovery of this new metal. It is of a white colour, inclining to grey, very hard, brittle, and extremely difficult of fusion. The small quantity which Vauquelin could procure, did not permit him to ascertain many of its properties.

It is but little altered by exposure to heat, and probably would be affected neither by the action of air nor of water. Acids act upon it but slowly; nitric acid gradually converts it into an oxide by communicating oxygen.

It is hardly to be supposed that a metal so recently discovered can have yet been applied to any use, However, Vauquelin has already observed, that its oxide may be used in the fabrication of glass and enamel; and it may even, perhaps, have been already employed, without suspecting it, in the mixtures of the products of minerals ill understood or analyzed, of which it may form a part.

OF MOLYBDENUM.

The name of molybdena, which was formerly synonymous with that of plumbago, or black lead, or the natural combination of iron and charcoal, or carburet of iron, is at present given to a brittle and acidifiable metal, of which the ore was confounded with that coally substance. Many considered them as one and the same substance, and they were sold under the same denomination, till Scheele, in 1778, published, in the volumes of the Stockholm Academy, a memoir, in which he showed that the substance called molybdena is very different from the carburet of iron, and contains a combination of sulphur, with a substance which he took for a peculiar acid.

Hitherto molybdenum has only been obtained in small agglutinated metallic grains; the greatest heat of our furnaces not being sufficient to melt it into a button. Hence we are but imperfectly acquainted with its properties.

The specimens procured by Hielm were of a yellowish white colour, and internally greenish white.

Its specific gravity he found as high as 7·400. From his experiments, compared with those of Klaproth and Buckolz, on uranium, it seems probable that molybdenum is even more refractory than that metal.

When exposed to heat in an open vessel, it gradually combines with oxygen, and is converted into a white oxide, which is volatilized in small brilliant needle-form crystals. This oxide, having the properties of an acid, is known by the name of *molybdic acid.*

OF TUNGSTEN.

The name Tungsten, which signifies heavy stone, was given by the Swedes to a mineral, which Scheele found to contain a peculiar metal, as he supposed, in the state of an acid, united with lime. The same metallic substance was afterwards found by Don d'Elhuyart united with iron and manganese in wolfram.

Tungsten is of a greyish white colour, or rather like that of iron, and has a good deal of brilliancy.

It is one of the hardest of the metals; for Vauquelin and Hecht could scarcely make any impression upon it with a file. It seems also to be brittle. Its specific gravity, according to the D'Elhuyarts, is 17·6; according to Allen and Aiken, 17·22. It is therefore the heaviest of the metals after gold and platinum.

It requires for fusion a temperature at least equal to 170° Wedgewood. It seems to have the property of crystallizing on cooling, like all the other metals; for the imperfect button procured by Vauquelin and Hecht contained a great number of small crystals.

Nothing has yet been observed respecting the uses of a metal so little known or examined as tungsten. No trial has yet been made with regard to its useful properties; and it is to be feared, that its reduction and fusion being difficult, will render it so intractable as not to be used but with great difficulty.

OF COLUMBIUM.

This metal was discovered by Mr. Hatchett, in a mineral belonging to the cabinet of the British Museum, supposed to be brought from Massachusetts, in North America.

Its lustre was glassy, and in some parts slightly metallic. It was moderately hard, but very brittle. By trituration it yielded a powder of a dark chocolate brown, not attracted by the magnet. Its specific gravity, at the temperature of 65°, was 5·918.

OF SELENIUM.

In 1819 M. Berzelius extracted a new elementary body from the pyrites Fahlun, which, from its chemical properties, he places between sulphur and tellurium, though it has more properties in common with the former than with the latter substance. It was obtained in exceedingly small quantity from a large portion of pyrites.

When it is fused it becomes solid, its surface assumes a metallic brilliancy of a deep brown colour. Its fracture is conchoidal, vitreous, of the colour of lead, and perfectly metallic.

OF OSMIUM.

This singular metal was discovered by Mr. Tennant, about the year 1804, in the ore of platina, combined with another metallic substance, which received the name of Iridium.

Osmium has a dark-grey or blue colour, and the metallic lustre. When heated in the open air, it evaporates with the usual smell; but in close vessels, when the oxidizement is prevented, it does not appear in the least volatile.

When subjected to a strong white heat in a charcoal crucible, it does not melt nor undergo any apparent alteration.

It is not acted upon by any acid, not even the nitro-muriatic, after exposure to heat; but when heated with potash it combines with that alkali, and forms with it an orange-yellow solution.

OF RHODIUM.

This metal is of a white colour. Its specific gravity seems somewhat to exceed 11. No degree of heat hitherto applied is capable of fusing it. It is, therefore, uncertain whether it be malleable; but as it forms malleable alloys with the other metals, it is probable that it would not be destitute of malleability, if it could be fused into a button.

OF IRIDIUM.

This metal was discovery by Mr. Smithson Tennant in 1803, in the ore of crude platina.

The iridium which was thus obtained was white, and could not be melted by any heat Mr. Tenant could employ. Vauquelin considers it as brittle, and as even occasioning the brittleness of platinum; but as it has not been obtained in a metallic button, and as it forms malleable alloys with all metals tried, that property does not seem to be sufficiently decided.

It resists the action of all acids, even the nitro-muriatic acid.

OF URANIUM.

This metal was discovered by Klaproth in a mineral which contains uranium combined with sulphur.

By treating the ores of the metal with the nitric or nitro-muriatic acid, the oxide will be dissolved, and may be precipitated by the addition of a caustic alkali. It is insoluble in water, and of a yellow colour; but a strong heat renders it of a brownish grey.

OF TITANIUM.

Titanium is obtained from a mineral found in Hungary, called red schorl, or titanite: and also in a substance from the valley of Menachan, in Cornwall, termed menachanite. It was in the latter substance that it was originally discovered by Mr. Gregor, of Cornwall; and its characters have since been more fully investigated by Klaproth, Vauquelin, Hecht, Lovitz, and Lampadius.

Its colour is that of copper, but deeper. It has considerable lustre. It is brittle, but in thin plates has considerable elasticity. It is highly infusible.

When exposed to the air, it tarnishes, and is easily oxidized by heat, assuming a blue colour. It detonates when thrown into red hot nitre.

OF CERIUM.

Cerium was discovered by Messrs. Berzilius and Hisenger, of Stockholm, in a mineral from Bastreas, in Sweden, to which they gave the name of Cerit, and which had been for some time before supposed to be an ore of tungsten. This discovery has since been confirmed by the experiments of Vauquelin.

OF WODANIUM.

This is a new metal, recently discovered by Lampadius in the mineral called *Woodan pyrites*. This metal has a bronze-yellow colour, similar to that of cobalt glance; and its specific gravity is 11·470. It is malleable; its fracture is hackly; it has the hardness of fluor spar; and is strongly attracted by the magnet.

It is not tarnished by exposure to the atmosphere at the common temperature; but when heated, it is converted into a black oxide.

ALKALINE AND EARTHY METALS.

The remaining substances contained in the table of metals, at page 361, vol. i, are the bases of the two fixed alkalies (Potash and Soda,) and of the eleven substances at present considered as earths.

The two first, Potassium and Sodium, as well as Barium, and a few of the others, were obtained by Sir H. Davy, by decomposing the Alkalies and Earths by galvanic electricity; whilst the others are *merely* considered as the metallic bases of the respective earths whose names they bear.

We are sorry that our limits will not permit us to give a more detailed account of these bodies.

ASTRONOMY.

OF THE QUANTITY OF MATTER IN THE SUN AND PLANETS, AND THE FORCE OF GRAVITY AT THEIR SURFACES.

On first view, it almost appears impossible to determine the respective masses of the sun and planets, and to measure the height from which bodies fall in a given time, by the action of gravity at their surfaces. But the connection of facts with each other, often leads to results which appear inaccessible, when the principle on which they depend is unknown.

It was, therefore, perfectly natural even for astronomers to consider it impossible to determine the intensity of gravity at the surface of the planets, while the principle of universal gravitation remained unknown;* and it is just as natural for those who are unacquainted with mathematics and astronomy to consider the same thing impossible, even although they have heard of such a principle as universal gravitation. We shall, therefore, state what has been the result of the calculation of some of the first-rate astronomers of the present day on this curious and interesting subject.

From the fact that action is always accompanied by re-action, astronomers conclude, that gravitation among terrestrial bodies is the mutual tendency of the particles of matter to one another. And, from analogy, they think it perfectly reasonable to suppose, that this is true in all cases; and that the force of gravitation towards different bodies, the distance being the same, is proportional to the quantities of matter, or the masses of the bodies.

This supposition is the foundation of all the calculations respecting the masses of the planets; and from it formulas have been deduced, for calculating the relative quantity of matter in such of the primary planets as have satellites revolving round them; but the quantity of matter in those that have no satellites, can only be guessed at by the effect they produce in disturbing the motions of the other planets.†

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* It was this discovery which rendered it practicable to measure the intensity of gravity at the surfaces of the planets.

† The quantities of matter in any two primary planets are direcly as the cubes of the mean distances at which their satellites revolve, and inversely as the squares of their periodic times.

The quantity of matter in the moon, however, may be determined by comparing its influence with that of the sun in producing the tides, and the precession of the equinoxes. By these means it has been ascertained, that the mass of the moon is about $\frac{1}{70}$th part of that of the earth. And La Place, in his *Mecanique Celeste*, has determined the quantity of matter in each of the primary planets, from the most exact data, to be as follows:—

Quantity of matter in the Sun .	1
Mercury . . .	$\frac{1}{2025810}$
Venus . . .	$\frac{1}{383137}$
The Earth . . .	$\frac{1}{329630}$
Mars	$\frac{1}{1846082}$
Jupiter . . .	$\frac{1}{1067 \cdot 09}$
Saturn . . ,	$\frac{1}{3359 \cdot 4}$
Uranus* . . .	$\frac{1}{19504}$

The masses of the planets being known, and their bulks being also known, their densities are easily determined, for these are proportional to the masses divided by the bulks.

La Place, taking the mean density of the sun as *unity*, finds the density of such planets as have satellites to be as follows: The Earth, 3·9395; Jupiter, 0·8601; Saturn, 0·4951; Uranus, 1·1376.

Knowing the masses of the planets, and their diameters, the force of gravity at their surface may be determined; for, supposing them to be spherical, and to have no rotation on their axis, the force with which a body placed on their surface gravitates to them, will be proportional to their masses divided by the squares of their diameters. From the masses of Jupiter and the Earth, La Place calculates that a body which weighs one pound at the earth's equator, if carrried to Jupiter's equator would weigh $2\frac{1}{2}$ pounds, supposing these bodies to have no rotation, and supposing the weights to be measured by the pressure exerted in the two situations. If the same body were carried to the surface of the sun, it would weigh about $27\frac{3}{5}$ pounds; from which it follows, that a heavy body would there descend about 444 feet in the first second of time.

Although all the planets gravitate to the sun, yet the centre of the sun is not the centre of gravity of the whole solar system. The centre of the sun is, however, never distant from that point so much as his own diameter, consequently the centre of gravity of the whole system is always within the body of the sun. But as this point and the centre of the sun do not coincide exactly, and as the gravitation of the planets to the sun must be accompanied by the gravitation of the sun to the planets, from the quailty of action and re-action, it follows that the sun must have a motion in a small orbit round the centre of gravity of the whole system. The form of this orbit is, however, very complicated, on account of the disturbing forces of so many planets, which are sometimes exerted toward one side and sometimes toward another; and even unequally exerted on different sides at the same time, according to the situation of the planets in their orbits.

Thus we see the extraordinary and universal principle called gravitation, has not only been the means of making us acquainted with a great number of inequalities in the motion of the heavenly bodies, which it would have been impossible to have discovered by observation, but it has furnished us with the means of subjecting these motions to precise and certain rules.

The motion of the earth, which had obtained the assent of astronomers, on account of the simplicity with which it explained the celestial phenomena, has received a new confirmation, which has carried it to the highest degree of evidence of which physical science is susceptible. Without the knowledge of this universal principle, the ellipticity of the planetary orbits; the laws which the planets and comets obey in their revolution round the sun; their secular and periodical inequalities; the numberless inequalities of the moon, and the satellites of Jupiter; the precession of the equinoxes; the nutation of the earth's axis; the motions of the lunar axis; and the ebbing and flowing of the sea, would only be insulated facts, and unconnected phenomena. It is, therefore, a circumstance which can scarcely be sufficiently admired, that all these phenomena, which at first sight appear so unconnected, should be explained by *one principle*—that of the mutual gravitation of all bodies with forces directly as their quantities of matter, and inversely as the squares of their distances.

OF THE PRINCIPAL SYSTEMS OF ASTRONOMY.

After the description which has been given of the various phenomena of the heavens, both as viewed with the naked eye and the telescope, it may not be unnecessary, nor unacceptable to the reader, to give a short account of the principal theories, or systems, which have been formed at various periods to account for some of these appearances, and particu-

* By adding these fractions together, it will be found that the quantity of matter in all the planets together is not $\frac{1}{600}$th part of the matter in the sun!

larly for the apparent motions of the celestial bodies,

The explanation of the celestial motions which naturally occurred to those who began the study of the heavens, was, that the stars are so many luminous points fixed in the surface of a sphere, having the earth in its centre, and revolving on an axis passing through that centre, in the space of twenty-four hours. When it was observed, that all the stars did not partake of this diurnal motion in the same degree, but that some were carried slowly towards the east, and that their paths estimated in that direction, after certain intervals of time, returned into themselves, it was believed that they were fixed in the surfaces of spheres, which revolved westward more slowly than the sphere of the fixed stars. The spheres were supposed transparent, or made of some crystalline substance, and from this arose the name of the crystalline spheres, by which they were distinguished. Though this system grew more complicated, as the number and variety of the apparent phenomena increased, yet it was the system of Aristotle and Euodxus; and, with few exceptions, of all the philosophers of antiquity.*

But when the business of observation came to be regularly pursued, little was said either of the fixed stars, or of the crystalline spheres; astronomers being chiefly bent on ascertaining the laws or general facts connected with the motions of the planets.

To do this, however, without the introduction of hypotheses, at this period, was scarcely possible. The simplest and most natural hypothesis was, that the planets moved eastward in circles, at a uniform rate. But when it was found that, instead of moving uniformly to the eastward, every one of them was subject to great irregularity, the motion eastward becoming slower, at certain periods, and at length vanishing altogether, so that the planet became stationary, and afterwards acquiring a motion in the contrary direction, and proceeded for a time to the westward, it was far from obvious that all these appearances could be reconciled with the idea of a uniform circular motion.

The solution of this difficulty is attributed to Apollonius Pergæus, one of the most celebrated mathematicians of antiquity. He conceived that each planet moved in a small circle, and that the centre of this small circle moved in the circumference of a large circle, which had the earth for its centre. The first of these circles was called the *epicycle*, and the second the *deferent;* and the motion in the circumference of each was supposed uniform. Lastly, it was conceived that the motion of the centre of the epicycle in the circumference of the deferent, and likewise the motion of the planet in that of the epicycle, were in opposite directions; the first being towards the east, and the second towards the west. In this way, the change from progressive to retrograde, as well as the intermediate stationary points, were readily explained.

But, notwithstanding the accomplishment of this important object, no regular system of astronomy appears to have been framed or taught by any individual till the appearance of the celebrated Ptolemy, who has always been reckoned the prince of ancient astronomers, not so much on account of being the founder of the system which goes by his name, as for the number of observations which he made, and the extent of his astronomical writings.

As we have already given an account of this, as well as the Tychonic and Copernican systems, at page 46, vol. i, we shall conclude this subject by giving a short description of the Cartesian system.

CARTESIAN SYSTEM.

The founder of this system, Rhènè Des Cartes flourished about the beginning of the 17th century. He supposed that every thing in the universe was formed from very minute bodies, called *atoms*, which had been floating in open space. To each *atom* he attributed a motion on its axis; and he also maintained that there was a general motion of the whole universe round like a *voxtex*, or whirpool. In the centre of this vortex was the sun, with all the planets circulating round him at different distances; those that were nearer the sun circulating faster than those at a greater distance, as the most distant parts of a vortex or whirlpool are known to do. Besides this general vortex, each of the planets had a particular vortex of its own, by which its satellites, if it had any, were whirled round, and any other body that came within its reach.

This is the celebrated system of vortices, invented by Des Cartes. The fabric, it must be confessed, is raised with great art and ingenuity, and is evidently the produce of a lively fancy and a fertile imagination. But then, it can be considered only as a philosophical romance, which amuses without instructing us; and serves

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* Although it is said that Pythagoras taught that the earth was a planet, and that the sun was fixed in the centre of the planetary system; that the apparent revolution of the heavens was produced by the diurnal revolution of the earth; and that the apparent annual motion of the sun was occasioned by the earth moving round him like the other planets; yet this doctrine was never taught publicly, and in a very short time it was completely forgotten.

principally to shew that the most shining abilities are frequently misemployed.

In this hypothesis, Des Cartes supposes extension to constitute the essence of matter, and wholly neglects *solidity*, as well as the *inertia* by which it resists any change in its state of motion or rest, which principally distinguishes body from space; and, consequently, the doctrine of an universal plenum, deduced from this definition, is founded upon false principles.

That there is such a thing as a vacuum in nature, or a space void of body, may be demonstrated from various experiments. By means of the air-pump, we can so far exhaust the air from a glass receiver, that a piece of gold and a feather, let fall together, from the top of the vessel, shall both descend equally swift, and come to the bottom at the same time: which evidently shews, that, the air being taken away, there remains no other matter sufficient to cause any sensible resistance, or that in the least impedes or obstructs their passage.

It was said by many of the ancient philosophers, that nature abhors a vacuum; and by means of this dogma, and others of a like nature, they attempted to prove and illustrate the doctrine of an universal plenum, like that of Des Cartes. But this is an assertion, unsupported by facts, and too idle a notion to require any formal refutation: and in nearly the same predicament are most of the other arguments which have been used in defence of this doctrine. They are all sufficiently exposed, not only by the Torricilian experiment, and the nature of pumps in general, but likewise from the most obvious phenomena of the constant and free motion of bodies, whether celestial or terrestrial, which come continually under our inspection.

On the system of Des Cartes, and all others that depend on the same principle, we may remark, that if the planets be carried round the sun in vortices, the quantity of matter in the sun cannot affect the velocity of the vortex, or the bodies immersed in it; consequently the velocity might be the same though there were no central body whatsoever. The quantity of matter in the sun, therefore, cannot have the least effect in retaining the planets in their orbits. But the quantity of matter in the sun does affect the planet, and is a material element in its gravitation towards the centre of its orbit. It is therefore impossible that the action of a vortex, can have any effect whatever upon that gravitation. This argument is perfectly conclusive and fatal to the sysem of vortices. But we may observe that this system owed its downfal to another argument, equally if not still more powerful; viz. that whenever you suppose the vortex so arranged that it will explain one of those great facts in the planetary motions, known by the name of Kepler's Laws, it becomes quite inconsistent with the rest.

The vortices of Des Cartes have, therefore, ceased to afford any satisfaction even to the most superficial reasoner, and are now only known in the history of opinions; in which they will ever furnish a most instructive chapter.

SOLUTIONS OF QUESTIONS.

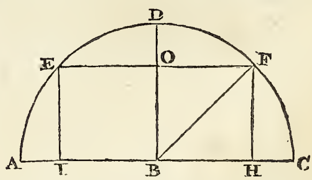
QUEST. 65* (page 112) *answered by* J. M. EDNEY, *Broad-street, Bloomsbury.*

Let $4x$ and $5x$ be the sums subscribed by each lady. Then by the quest. $4x)^2 + (5x)^2 = 69{\cdot}5.9\frac{6}{10} = 69{\cdot}29$; that is, $41x^2 = 69{\cdot}29$, or $x^2 = 1{\cdot}69$, and $x = 1{\cdot}3$. Hence $4x = 5{\cdot}2 =$ £5 4s.; and $5x = 6{\cdot}5 =$ £6 10s. the sums required.

This question was also correctly answered by Mr. J. HARDING, Mr. J. WHITCOMBE, and by the Proposer.

QUEIT. 66, *answered by* Mr. J. WHITCOMBE, *Private Teacher of Mathematics, Lothbury.*

Let A D C denote the given semicircle,



and let D B divide it into two equal quadrants. Bisect the quadrantal arch D C in F, by the radius B F; draw F H parallel to D B, and draw F E parallel to A C, also E I parallel to D B and F H, and the thing is done; for I E F H is the parallelogram, whose area is a maximum.

DEMON. As the quadrantal arch D C is bisected in F by the radius or diagonal line B F, it is evident the angles F B H, O B F, H F B, and B F O are equal, consequently the rectangle B O F H is a square: then per Simpson's Geometry, Theo. V, on Maxima and Minima, the triangles B F H and B F O are each of them a maximum, because they are each Isoceles: consequently the rectangle B O F H is also a maximum. It is also evident that the rectangle B O F H is half the parallelogram I E F H; hence it is manifest that this parallelogram is also a maximum.

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* By mistake this question was numbered the same as one at page 96.

The Editor takes this opportunity of thanking his Mathematical Correspondents for their respective Communications during the progress of the Work; and is happy to find that his labours and discrimination, in this department at least, have given satisfaction to all.

He also thinks it proper to inform them, as the Work is now concluded, that the Solutions to the first *nine Questions,* with the exception of the 6th and 7th, were supplied by himself, as well as the 14th, 19th, 23d, 24th, 40th, 43d, 52d, 56th, 59th, and 62d.

THE END.

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