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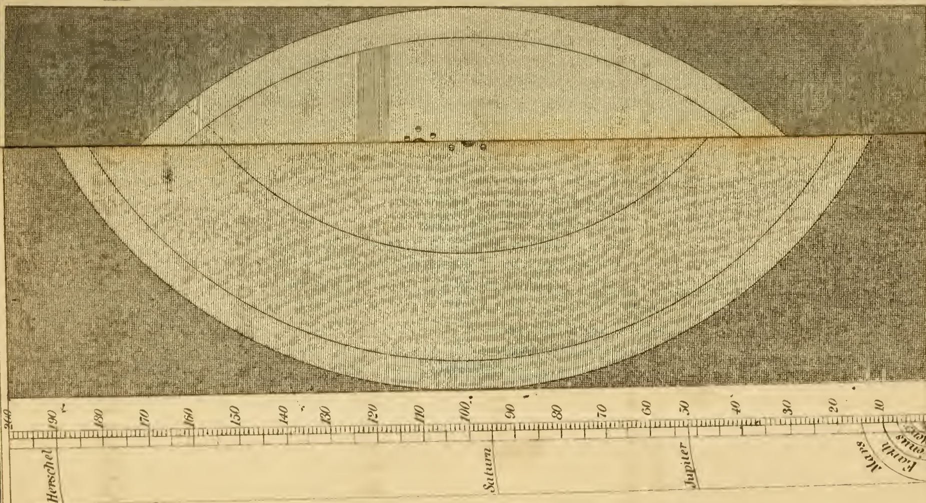

Comparative Distances of the Planets from the Sun

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GUY'S

ELEMENTS OF ASTRONOMY,

AND

AN ABRIDGMENT

OF

KEITH'S NEW TREATISE

ON THE

USE OF THE GLOBES.

NEW AMERICAN EDITION, WITH ADDITIONS AND IMPROVEMENTS, AND AN EXPLANATION OF THE ASTRONOMICAL PART OF THE

AMERICAN ALMANAC.

THIRTIETH EDITION.

PHILADELPHIA:
CHARLES DESILVER,
1229 CHESTNUT STREET.
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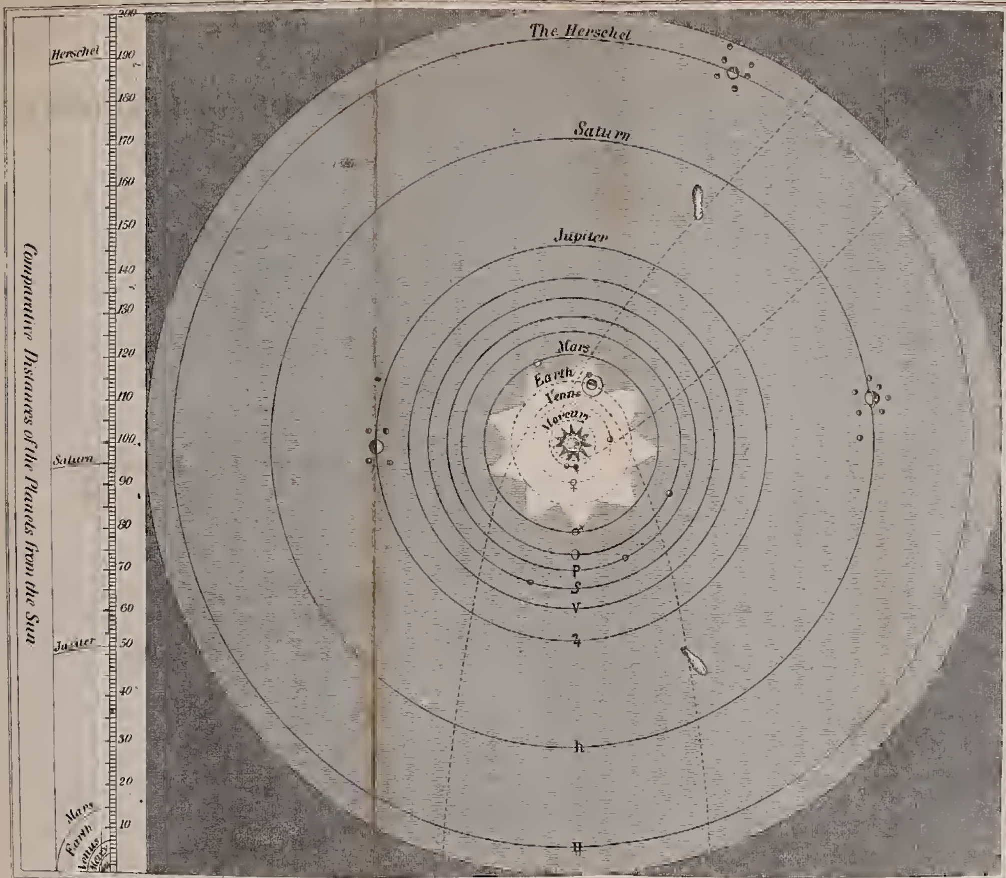
FRONTISPIECE to Guy's School Astronomy



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PREFACE.

That Astronomy is now considered a needful and important branch of knowledge for every well educated person, will be readily allowed; for however some minds, totally uncultivated, may, "with brute unconscious gaze," raise their eyes to the starry firmament, or behold the various phænomena that result therefrom, still, to those who hold a respectable rank in society, a *general acquaintance at least*, with the order of the heavenly bodies, and the laws by which they are governed, must at some time necessarily become a part of their inquiries.

Hence, where it is practicable, it seems highly desirable that that which *must* be known should be begun early, or made a branch of school education; at least the elements of the science, or great leading principles should be then inculcated.

That there are many great and scientific works, and some popular volumes already published, is well known; and if this compendium is added to the number, it is not for the sake of obtruding the author once more before that public which has so favourably countenanced his former works, but because he has not, after a solicitous search, found any treatise expressly designed and practically drawn up as a *class book for schools.*

He acknowledges the free use which has been allowed him of some works on the subject, from which he has extracted valuable materials. Indeed, in a few instances, it will be seen that he has preferred rather to select *verbatim* from respectable authorities, than to distort the sentences (as is sometimes done) for the sake of an apparent originality. Far, however, from attempting to set aside the use of those valuable works which should have a place in every library, this is intended only to become the handmaid to them.

As the study of the same branch of science is often commenced by persons, not only of different ages, but of different capacities, and variously circumstanced in point of assistance, so must the modes of instruction, and the treatises proportionably vary. That treatise which may be well adapted to the solitary and self-taught student, or that which may, by its diversified reflections, captivate a leisure hour, may not be the best suited to the boy who studies in conjunction with his class fellows, and with the elucidations of a master always at hand.

As an elementary work, care has been taken to avoid two very common evils,—that of *extreme brevity* on the one hand, and of a *too great prolixity* on the other. A mere outline, or brief mention of a very few leading particulars, could not prove satisfactory, either to teacher or learner; it would call forth no exertion, excite no interest, afford no pleasure, impress no lasting improvement. On the other hand, to swell the volume with complicate calculations, and by the discussion of subjects too abstruse for juvenile comprehension, would occasion the *Tyro* to stumble at the threshold, and recoil from the study in hopeless disgust.

The text or *larger print*, may be considered to contain the general principles and well authenticated facts; or at least, so much of the outline of the science as should be first known. This therefore may be appointed for the learner's *first course*.

The *smaller print*, except what refers to illustrations of the plates may be omitted, or not formally insisted on, till the *second course*; as it contains matters either less known, or of less immediate importance; or else more difficult to be comprehended.

Perhaps there is not a point in which instructors more widely differ than in their opinion of the *quantum* proper to be put before the pupil. The vast dissimilarity in the bulk of elementary treatises, on any one subject, proves the truth of this assertion. One teacher prefers a volume for his pupil that contains almost every minutia, though it may require the toil of years to wade through it;—another presents him with a meagre outline that will not require the labour of as many months.

While this difference of opinion exists, and it will more or less ever exist, it may be desirable to meet, as much as possible, the views of each. This has been attempted in some late publications; and the plan is here followed by a *distinction in the type*. It is herein intended, that the *text*, if perused *alone*, should contain in itself a *connected and tolerable complete outline;* and if *read with the smaller type*, that the work should exhibit but *a more enlarged whole.* This simplicity in the arrangement will, it is hoped, render it more accommodating to instructors, and suit it to the purposes of scholars of different classes, capacities and ages. That work must surely possess some advantages, that can be perused by the younger scholar without perplexity, and by the more advanced student without deficiency.

General principles only of an art or science, it is well known, are the parts proper to be first committed to memory; and that too, perhaps, at an age when their utility is not known, nor to what purposes they are applicable. This is best effected, as Dr. Lowth observes, "by some short and clear system." Every one is aware of the impropriety of surcharging the bodily organs,—but overloading the yet unexpanded faculties of the mind, by an attempt to fill it with a too great redundancy of ideas in a first course, is equally fruitless and injurious.

It is particularly recommended that those young persons who wish to derive information from this treatise, will not only peruse it deliberately, and digest what they read, but *make a study of it*, so as to be able to answer with considerable correctness the questions subjoined. From a mere cursory perusal, neither information nor entertainment can be expected.

It is hoped that the *numerous well executed plates* which accompany this work will be deemed appropriate to elucidate the subjects; and that the complete *series of questions* will prove generally acceptable to instructors, and contribute to facilitate their labours.

It is presumed that most of the interesting parts of Astronomy have been introduced. To have illustrated the method of *calculating* Eclipses, and the transits of Mercury and Venus; or of finding the longitude and the periodic times and distances of Jupiter's satellites, &c. might have enhanced the work in the public estimation, but to the learner it would prove not only useless, but perplexing and obscure.

Indeed, to have handled the subject more abstrusely, and to have written in all the technical phraseology of the science, would have been much more easy than was the frequent labour of verbal discrimination, of casting into shade some parts which would only dazzle and bewilder, and of clothing other parts in a language, not less pure it is hoped, but at least more suited to the youthful comprehension.

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EXPLANATION OF SIGNS.

☉ The Sun.
☾ The Moon.
⊕ The Earth.
☿ Mercury.
♀ Venus.
♂ Mars
♃ Jupiter.
♄ Saturn
♅ Uranus
⚳ Ceres.
⚴ Pallas
⚵ Juno.
⚶ Vesta

Fig. 1

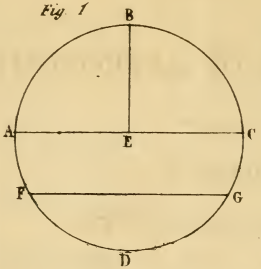
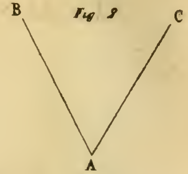


Fig 2



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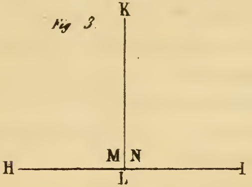
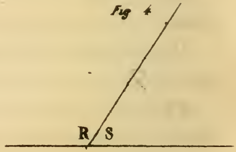


Fig 4



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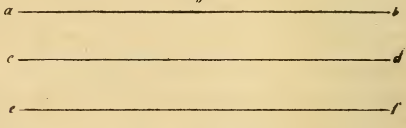

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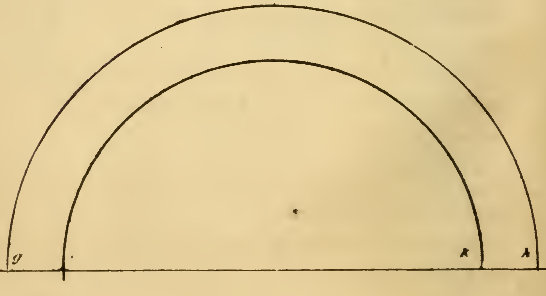


ELEMENTS OF ASTRONOMY.

CHAPTER I.

PRELIMINARY DEFINITIONS.

ASTRONOMY is that branch of natural philosophy which treats of the heavenly bodies: it consists of two parts, namely, *descriptive* and *physical* Astronomy.

Descriptive Astronomy, comprises an account of the phenomena of the heavenly bodies.

Physical Astronomy consists in the investigation of the causes of their motions, &c.

A *Circle* is a plain figure, bounded by a uniform curve line, called the circumference, which is every where equidistant from a certain point within, called its centre, as A B C D (pl. 1. fig. 1.)

The circumference itself is often called a circle, and also the periphery.

The *Radius* of a circle is a line drawn from the centre to the circumference; as A E, E B, or E C (fig. 1.)

The *Diameter* of a circle is a line drawn through the centre, and terminated at both ends by the circumference, as A E C (fig. 1.)

Every Diameter is double the radius, and divides the circle into two equal parts. The terminating points of the diameter are sometimes called its Poles, as A and C.

An *Arc* of a circle is any part of the circumference as F D G (fig. 1.)

A *Chord* of a circle is a right line joining the ends of an arc; dividing the circle into two unequal parts, as F G (fig. 1.)

A *Semicircle* is half the circle, or a segment cut off by the diameter, as A B C (fig. 1.)

The half circumference is sometimes called the Semicircle.

A *Quadrant* is half a semicircle, or one fourth part of a whole circle; as A E B, or B E C.

A quarter of the circumference is sometimes called a Quadrant.

All circles, great or small, are supposed to be divided into 360 equal parts, called degrees (marked °;) each degree into 60 minutes (marked ′;) each minute into 60 seconds (marked ″.) Hence a semicircle contains 180 degrees, and a quadrant 90 degrees.

An *Angle* is the meeting of two lines in a point, as A (plate 1, fig. 2.)

The point where they meet is called the angular point, and the lines A B and A C, are called sides or legs.

A *Right Angle* is that which is made by one line perpendicular to another, or, when the angles on each side are equal to one another, they are right angles; as the angles M and N (fig. 3.)

The measure of a right angle is a quadrant of 90 degrees.

An *Acute Angle* is less than a right angle, as the angle S (fig. 4.)

An *Obtuse Angle* is greater than a right angle, as the angle R (fig. 4.)

Parallel Lines, whether straight or circular, are lines in the same plane, which are every where at the same distance from one another; and which, though drawn ever so far, both ways, will never meet: thus *a b* and *c d* and *e f* (fig. 5,) are three parallel lines: and *g h* and *i k* (fig. 6,) are two parallel semicircles.

A *Globe* or *Sphere* is a round body, every part of whose surface is equally distant from a point within, called its centre.

A *Spheroid* is a figure nearly spherical, either oblong or oblate. The earth is a spheroid, having its *axis* or diameter at the poles *shorter* than at the equator.

A *Great Circle*, A B D E, of a sphere, is one whose plane passes through its centre C. (See plate 2, fig. 1.)

A *Small Circle* of a sphere, F G H I, is that whose plane does not pass through its centre.

A *Diameter*, N C S, of a sphere, perpendicular to any great circle, is called the axis of that great circle, and the extremities, N S, of the axis, are called its poles. (Plate 2, fig. 1.)

Hence the pole of a great circle is 90° from every point of the diameter upon the sphere; because every angle, as *N C A*, being a right angle, the arc, N A, is every where 90 degrees.

Any two great circles bisect each other; for the planes of both passing through the centre of the sphere, their common section must be a diameter of each; and every diameter bisects a circle.

The *Axis* of the earth is that diameter about which it performs its diurnal revolution.—See plate 2, fig. 2, where *p e p q* represent the Earth, and *p O p* the axis.

CHAPTER II.

Astronomy is that science which teaches the knowledge of the celestial bodies, the sun, moon, planets, comets, and fixed stars; with their magnitudes, motions, distances, periods, eclipses, and order.

The general opinion of astronomers of the present day is, that the universe is composed of an infinite number of systems of worlds: in each of which there are certain bodies moving in free space, and revolving, at different distances, round a sun, placed in or near the centre of each system; and that these suns are the stars which are seen in the heavens.

Among the heavenly bodies the Sun and Moon are termed *luminaries;* the others are called *stars.* Stars are also distinguished into *planets* and *fixed stars.*

The PLANETS, though they appear like the fixed stars, are all opaque, or dark bodies, moving in a regular order round the sun, from west by south, to east, receiving their light from him, and shining by reflecting his light.

Some of the planets have attendants or satellites moving round them, as their centres, and with them round the sun. There is also another order, called *comets*, with blazing tails, which pursue very eccentric courses.

The names of the planets are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and Uranus or Herschel; with four smaller ones, called Asteroids, namely, Vesta, Ceres, Pallas, and Juno.

Vesta, though the last discovered of the asteroids, is, according to some authorities, nearer to Mars than either of the other three; but, according to others, Juno is placed the nearest.

These are all called *primaries*; and there are also eighteen satellites or moons, called *secondaries.* The Earth has one; Jupiter, four; Saturn, seven; and Uranus, six. No moons have hitherto been discovered to belong to the other planets.

Fig. 1.

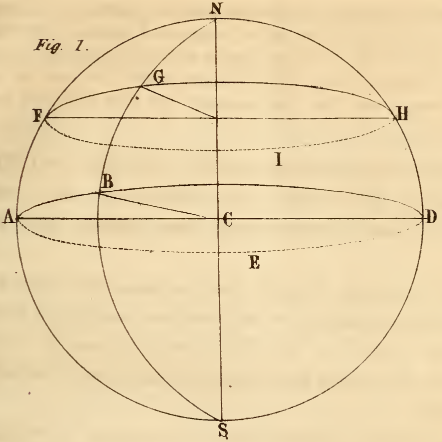
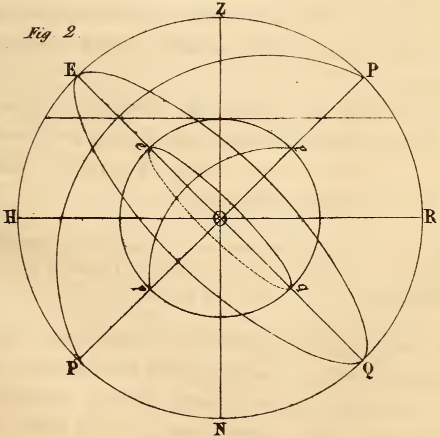


Fig. 2.



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Correctly speaking, the satellites are *planets*, as well as those round which they revolve; for planet is derived from the Greek word πλανητης, signifying roving or wandering.

THE SUN.

The Sun is the source of light and heat. and the centre of our Solar or Planetary System. His form is nearly that of a sphere or globe. His diameter is about 883,210 miles, and his circumference 2,774,692 miles.

According to some authorities the Sun's diameter is 893,522 miles. For the definition of a *globe* or *sphere*, see the *Preliminary Definitions* Chap. I. The Sun's diameter is equal to 112 diameters of the earth.

His distance from the earth is 95,000,000 of miles; and he is 1,400,000 times larger than our earth. The Sun was for ages, and till lately, thought to be a globe of real fire; but it is now supposed to be an opaque body, surrounded by a luminous atmosphere.

Though to the Sun our earth is indebted for light and heat, life and vegetation, and without its genial influence it would become a dark inert mass, yet Dr. Herschel supposes the Sun to be an opaque body, surrounded by a lucid and transparent atmosphere; that this luminary differs but little in his nature from the planets; and that it is an inhabitable world.

A number of *maculæ*, or dark spots, may sometime be seen, by means of a telescope, on different parts of the Sun's surface. These consist of a *nucleus*, which is much darker than the rest, surrounded by a mist or smoke; and they are so changeable as frequently to vary during the time of observation. Some of the largest of them seem to exceed the bulk of the whole earth, and are often seen, at intervals of a fortnight, for three months together. The darker spots are termed *maculæ*, and the brighter *faculæ*.

The *maculæ* have been supposed by some, to be cavities in the body of the Sun; the nucleus being in the bottom of the excavation; and the shady zone surrounding it, the shelving sides of the cavity. Others have supposed maculæ to be large portions of opaque matter moving in the fiery fluid. Some again have taken them for the smoke of volcanoes in the Sun, or the scum floating upon a huge ocean of fluid matter. *Faculæ*, on the contrary, have been called clouds of light, and luminous vapours. But Dr. Herschel supposes that the Sun is surrounded by an atmosphere of a phosphoric nature, composed of various transparent and elastic fluids, by the decomposition of which, light is produced, and lucid appearances formed, of different degrees and intensity.

The Sun has two motions: the one is a periodical motion, in nearly a circular direction round the common centre of all the planetary motions (see the article, *Centre of Gravity*, Chap. XIX.)—the other motion is a revolution upon its axis, which is completed in about twenty-five days.

The Sun's motion about its axis renders it spheroidical, having its diameter at the equator longer than at the poles.

The method of ascertaining the Sun's revolution on his axis is, by observing the motion of some of those remarkable spots which are seen on his disc. If these spots are observed uniformly to change their places, and to appear on one side and disappear on the other, there is not any other means of explaining such phenomena, but that of a rotation about his axis.

The time of rotation may be found by observing the arc described by any spot in a given time, and then find by proportion the time of describing the whole circle. Or the return of the spot to the same position with respect to the earth may be observed, which will give the time of an entire rotation.

The Sun, if viewed from any other system in the universe, would appear as a fixed star does to us.

CHAPTER III.

MERCURY.

Mercury* is the smallest of the inferior planets, and the nearest planet to the sun. His diameter is above one third of the diameter of our earth, or about 3,000 miles. He revolves about the sun in 87 days, 23 hours, and $\frac{1}{4}$, at the distance of about 37,000,000 of miles from that luminary; moving in his orbit at the amazing rate of above 112,000 miles an hour, or 31 miles in a second.

By the term *orbit* is meant, the path described by a planet in its course round the sun, or by a moon round its primary planet.

For an illustration of the planets' orbits, see the Frontispiece.

Some authorities make Mercury's diameter 200 miles more, and others as much less. His mean distance from the sun is to that of the earth from the sun, as 387 to 1,000, or considerably more than one-third.

Though small, he has a bright appearance, with a light tint of blue; he never departs much more than 30° from the sun, and on that account is usually hid in the splendour of that luminary.

The sun's diameter will appear, if viewed from Mercury, nearly three times as large as from the earth. And the sun's light and heat at Mercury, have been calculated at above seven times those of the earth: upon the supposition that the materials of which Mercury is composed, are of the same nature as those of our globe.†

Mercury's diurnal motion, or time of rotation on his

---

* Mercury, was considered, mythologically, as the messenger of the gods.

† These degrees of heat and light are presumed, upon the long and generally received opinion, that the sun is a globe of fire.

axis is 24 hours and 5 minutes, and the inclination of his axis to his orbit is very small.

Mercury changes his phases in a manner similar to the moon, according as he is stationed with regard to the earth and sun.

This planet, however, never appears to us quite full; because when his bright side is turned fully to us, he is lost in the sun's beams. From these different phases it is clear that he does not shine by his own light; for if so, he would appear always round.

As the orbit of this planet is between the earth's orbit and the sun, he will at times appear to pass exactly between them; and this appearance is denominated *the transit of Mercury over the sun's disc:* the planet then appearing like a black spot moving across the face of the sun.

As the planes of the earth and Mercury's orbits are not coincident, this appearance does not often happen. The last transit happened, Nov. 5, 1822; a second will happen, May 5, 1832; and another, Nov. 7, 1835

VENUS.

Venus is the second planet from the sun, and is easily distinguished by her superior brightness and whiteness. Her mean distance from that luminary is about 69,000,000 of miles, and she completes her annual revolution in less than 225 days, with a rotation about her axis in 24 hours nearly.

Hence, the length of her year is not quite two-thirds of ours Bianchini makes a complete rotation on her axis to be 24 hours 8 minutes; but the Cassinis, 23 hours 20 minutes; and Schroeter 23 hours 21 minutes.

The circumference of her orbit is at least 432,000,000 of miles.

Her magnitude is nearly the same as that of the earth. her diameter being about 7,900 miles; and she moves in her orbit at the rate of 75,000 miles in an hour.

The quantity of light and heat which this planet receives from the sun, may be supposed to be double that of the earth. Her lustre is so great that she has been seen in the day-time, when the sun shines ; and at night she usually projects a real shade.

Venus, when viewed through a telescope, is neve seen to shine with a bright full face. But she ha phases changing like the moon ; for sometimes she appears gibbous, at others, horned like the *new moon*, and her illumined part is constantly towards the sun ; which proves that she moves, not round the earth, but round the sun.

Venus is a *morning star* when seen by us westward of the sun, for then she rises before him ; and an *evening star* when eastward of that luminary, for then she sets after him.* She is alternately the one and the other about 290 days.

In her seasons there must be a very considerable difference ; much more, indeed, than is experienced by us. The axis of our earth is inclined only 23½ degrees, whereas that of Venus inclines about 75 degrees to the plane of her orbit.

Venus appears much larger at sometimes than at others ; and the great variations of her apparent diameter demonstrate that her distance from the earth is exceedingly variable This great inequality, with respect to *distance* between her *superior* and *inferior* conjunctions, will appear from an inspection of plate 7 fig. 2. See also page 37.

The orbit of Venus, like that of Mercury, lying between the earth and sun, there will happen, at times,

---

* When a *morning star*, she is called, in the language of the poets *Phosphorus*, or *Lucifer* : and *Hesperus* or *Vesper*, when an *evening star*

what is denominated *the transit of Venus*, or the passing of this planet over the sun's disc, in the form of a *dark round spot*: this occurs only twice in about 120 years.

One was seen in England in 1639, one in 1761, and one in 1769: only two will happen in the present century, viz. the first in 1874, the last in 1882.

By this phænomena astronomers have been enabled to ascertain the distance of the earth from the sun; and hence the distances of the other planets are easily found. Kepler was the first person who predicted the transits of Venus and Mercury over the sun's disc. And the first time Venus was ever seen upon the sun, was on Nov. 16, 1639 by our countryman, Mr. Horrox, who was educated at Emanuel College, Cambridge. See a fuller Illustration, Chap. XXXI

CHAPTER IV.

THE EARTH.*

The Earth is the third planet from the sun; its mean distance from him being about 95,000,000 of miles its diameter is found to be 7,920 miles, and its circumference to be 24,880 miles.

Doubtless, to a person placed on the planet Venus, the Earth would have as much the appearance of a star as Venus has to us.

The Earth has two constant motions; the one about its axis, and the other through its orbit round the sun. It moves in its orbit at the rate of 68,000 miles an hour, which is nearly 20 miles each moment; and performs an entire revolution in nearly 365¼ days, which

* The Earth by the ancients was called *Terra*; and by astronomers *Tellus*.

is the length of our year. A complete rotation upon its axis forms a natural day of 24 hours.

The more exact time of its *annual* motion is 365 days, 5 hours, 48 minutes, and 49 seconds.

Hence the division of time into *days* and *years* are prescribed by the motions of the Earth; the *former* depending upon the rotation of the Earth upon its axis; the *latter* upon its revolution in its orbit.

The *form* of the Earth is not that of an exact globe or sphere, but of a spheroid, i. e. a little flatted at the poles, having the diameter at the equator, 26 miles longer than at the poles

The earth was formerly supposed to be a wide extended plane, firmly fixed upon something, which it was impossible to describe; but from more recent observations, which will hereafter be explained, it is proved to be nearly globular.

The earth serves as a great satellite to the moon, and subject to nearly the same changes as that body undergoes. But the Earth appears more than thirteen times larger when viewed from the moon, than the moon appears to us; and hence far more luminous. So that when it is new moon to our earth, it is a full earth to the moon, and the contrary.

It may, perhaps, be inaccurate to denominate the larger body a *satellite* to the smaller.

For an illustration of the motions of the Earth, causing the different lengths of days and nights, and of the different seasons, see Chap. XXV., &c.

THE MOON.

THE MOON is a satellite to the earth we inhabit, about which it revolves in an elliptic orbit, from one new moon to another, in 29 days, 12 hours, and 44 minutes, very nearly.

The above is called a *synodical* month. But the Moon revolves from one point in the heavens to the same point again, in 27 days, 7 hours, and 43 minutes, which is called a *siderial* or *periodical* month. These distinctions will be illustrated in Chap. XXVII.

The Moon's mean distance from the earth is 240,000 miles, and she moves in her orbit at the rate of about 2,290 miles in an hour.

Her diameter is 2,160 miles; and her bulk about a fiftieth part of the earth's. She always keeps the same side towards the earth; hence her rotation on her axis is performed in the same time as her revolution through her orbit; and hence it appears also that her day and night, taken together, are just as long as our lunar month; each being as long as from new moon to full moon.

She accompanies the earth in its annual orbit; and during that period, goes herself nearly thirteen times round the earth in an orbit of her own. Hence her year does not consist of quite thirty days. The different forms of increase and decrease which she presents, during the time of each revolution, are called the *phases of the Moon.*

The Moon, like the other planets, is a dark, or opaque body, borrowing her light from the sun; hence, only that half which is turned towards him at any time, can be fully illuminated; the opposite half would remain in darkness, if it were not for the light reflected from our earth. Therefore, as the light of the Moon, visible on the earth, is on that part of her body turned towards us, we shall, according to her different positions, perceive different degrees of illumination. Hence she appears sometimes waning, sometimes horned, then half round. If, on the contrary, the moon were a luminous body, she would always shine with a full orb, as the sun does.

It has been already noticed that our earth is a satellite to the Moon, as is evident soon after the change; for then her hemisphere towards us is illuminated by light which the earth reflects.*

The Moon's axis is almost perpendicular to the plane of the ecliptic; consequently she can have no diversity of seasons.

The inclination of her axis is only 1° 43′

The shades which appear on the face of the Moon, are found, when viewed through a telescope, to result from the diversity of mountains and valleys.

Some of the mountains in the Moon were formerly supposed to be five miles high; but Dr. Herschel has determined with greater precision than former astronomers, that very few of them exceed half a mile in perpendicular elevation. He has also observed several volcanoes in the Moon, emitting fire, as those on the earth do. Two of them appeared to him nearly extinct, but a third showed an actual eruption of fire, or luminous matter. When the Moon is either horned or gibbous, the irregularity of her surface is clearly discerned by the border of the Moon appearing indented or jagged, especially about the edge of the illumined part. See plate 18.

The Moon at her *conjunction* is invisible to us: her first appearance afterwards is called *new moon;* in *opposition* her whole disc is enlightened; it is then called full moon.

One remarkable circumstance relating to the Moon is, that the hemisphere next the earth, can never be really dark; for when it is turned from the sun, it continues illuminated by light reflected from the earth, in the same manner as we are enlightened by a full moon. But the other hemisphere of the Moon has a fortnight's light, and a fortnight's darkness by turns.

* The Greeks gave to the Moon the name of *Selene.*

The sun and stars rise and set to the inhabitants of the Moon, in a manner similar to what they do to us; and we are led to conclude that, like the earth, the Moon is also inhabited.

No large seas or tracts of water have been observed in the Moon by Dr. Herschel, or any other astronomer, nor did he notice any indications of a Lunar atmosphere. Recent observations, however, on the occultations of Jupiter and Venus by the Moon, render it highly probable that the Moon, as well as the earth, is surrounded by an atmosphere On April 5th, 1824, Mr. Ramage, of Aberdeen, Captain Ross, of the Navy, and Mr. Comfield, at Northampton, observed, with excellent telescopes, the occultation of Jupiter, and to all of them the disc of the planet appeared distorted when it approached the limb of the Moon; and Mr. Comfield, at Clapham, on Oct. 30th, 1825, observed, on the emersion of Saturn from behind the dark limb of the Moon, first the disc of the planet, and then the eastern extremity of the ring decidedly flattened, a phænomena perfectly analogous to what would be produced by refraction, and therefore rendering it highly probable that the Moon is surrounded by an atmosphere.

CHAPTER V.

MARS.*

The orbit of Mars is next above that of the earth, and he is the first of what are called *superior* planets. He is known in the heavens by a dusky red appearance. His distance from the sun is 143,000,000 of miles; and the length of his year is about 687 of our days.

The cause of his dusky red colour has not been clearly ascertained; whether it arises from a thick atmosphere, or from his being of a nature the better to reflect the red rays of light. The *mean distance* of Mars from the sun is more than half as far again as that of our earth

* The ancients have given the same name to the heathen *God of war*

that is, if the distance of the earth be considered to consist of 100 parts, that of Mars would be 152.

He moves in his orbit at the rate of 53,000 miles in an hour. The diurnal motion of this planet on its axis is performed in 24 hours and 39 minutes. His diameter is only 4,189 miles ; and owing to his distance he is supposed not to possess one half of the light and heat which we enjoy.

The *diurnal* motion of Mars is ascertained by several spots that are seen in him, when he is in that part of his orbit which is opposite to the sun and earth. Dr. Hook first discovered them, and Cassini and Herschel have from them, at length, determined his motion on his axis.

Though Mars, when viewed through a telescope, appears mostly full, yet he is seen, at times, to increase and decrease somewhat like the moon ; with this exception, that he is never horned. Hence we infer that he shines not by his own light ;—that his orbit exceeds that of the earth, and includes both the earth and the sun. No satellites or moons have been discovered to attend on Mars. See plate 5.

Mars, when in the part of the heavens opposite to the sun, appears about five times larger than when he is near the sun ; which proves that he must be much nearer to the earth in one situation than in another. This will receive illustration by an inspection of plate 7, fig. 2, where the great inequality, with respect to distance, is seen between his *opposition* and *conjunction*. It is evident, also, that it is not the earth that is in the centre of his motion, but the sun.

ASTEROIDS.

Between the orbits of Mars and Jupiter, four small planets, called Asteroids, have lately been discovered, viz. Vesta, Ceres, Pallas, and Juno.

Vesta, though the last discovered, is nearer to Mars than the other three : its mean distance from the sun being 225,000,000 miles; and the revolution through its orbit is performed in 1,326 of our days. Its inclination to the ecliptic is $7\frac{1}{7}$ degrees, being rather more than that of Mercury. The size of this planet is not yet ascertained.

Vesta was discovered by Dr. Olbers, a physician of Bremen, in Germany, early in 1807. This planet is much smaller than our moon.

Ceres's mean distance from the sun is 263,000,000 miles, not quite three times that of the earth. Its time of revolution is 4 years, 7 months, and 10 days; its diameter 1,582 miles, and it is inclined to the ecliptic in an angle of about $10\frac{1}{2}$ degrees.

Ceres was discovered by M. Piazzi, of Palermo, in Sicily, January 1, 1801.

Pallas's mean distance from the sun is nearly the same as that of Ceres; not quite three times that of the earth, namely 263,000,000 miles. Its revolution is made in about four years. Its orbit is inclined to the ecliptic, in an angle of about $34\frac{1}{2}$ degrees; and its diameter is 2,280 miles.

Pallas was discovered by Dr. Olbers, in March 1802.

Juno's mean distance from the sun is 252,000,000 miles; and its size nearly equal to that of Ceres. It revolves round the sun in 4 years and 4 months; and its diameter is 1,393 miles Its inclination to the ecliptic is 13 degrees; and it appears like a star of the eighth magnitude.

Juno was discovered by M Harding of Lilienthal near Bremen Sept. 1st, 1804

Fig. 1.

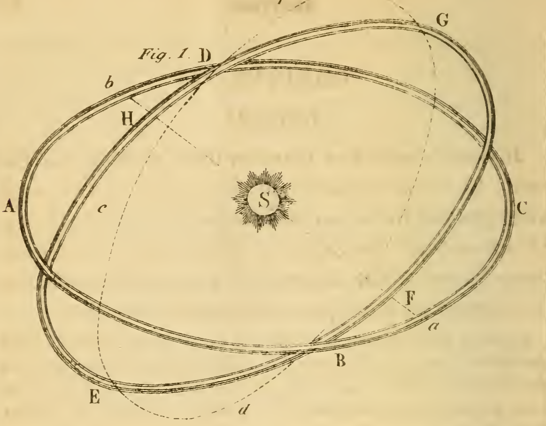


Fig 3.

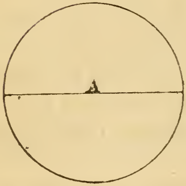


Fig. 2

Fig 4.

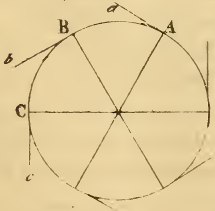
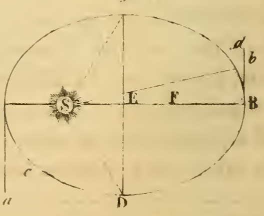


Fig. 5



CHAPTER VI.

JUPITER.*

Jupiter's orbit lies between those of Mars and Saturn; he is the largest of all the planets, and is easily distinguished by his peculiar magnitude and brilliancy. He exceeds all the planets in brightness, except sometimes Venus. The *distance* of Jupiter from the sun is estimated at more than 490,000,000 of miles.

Jupiter's mean distance from the sun is 52 of those parts of which the earth's distance is 10; hence, he is full five times farther from the sun than the earth is. And if it be admitted that light and heat diminish in proportion as the squares of the distances increase, the inhabitants of Jupiter receive but a 25th part of the sun's light and heat that we enjoy. See plate 18.

Jupiter's *diameter* is more than ten times that of the earth, it being 89,170 miles; and therefore his magnitude is about 1,300 times that of the earth.

His year is nearly equal to 12 of ours, for he makes one revolution round the sun in 4,332 days and a half: consequently he travels at the rate of more than 25,000 miles in an hour.

Jupiter revolves on his axis, which is perpendicular to its orbit, in less than 10 hours, at the amazing rate of 26,000 miles an hour, a velocity 25 times greater than the earth's. Hence, by this swift diurnal rotation, his equatorial diameter is 6,000 miles greater than his polar diameter. And as the variety in the seasons of a planet depends upon the inclination of its axis to its orbit, and as Jupiter has no inclination, there can be

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* The great heathen deity is characterized by this name.

no difference in his seasons, nor any variation in the length of his days and nights.

Jupiter's days and nights are always 5 hours each, in length, and about his equator there is perpetual summer; and an everlasting winter in his polar regions. If the axis of this planet were inclined to his orbit any considerable number of degrees, it might be less habitable about the poles; for then each pole would be nearly six years together in darkness.

When viewed through a telescope, Jupiter is perceived to be surrounded by faint substances, called *zones* or *belts*. These belts are generally parallel to its equator, and which is very nearly parallel to the ecliptic. They are subject to great variations both in number and figure. Sometimes eight have been seen at once; sometimes only one. Sometimes they continue for three months with little or no variation, and sometimes a new belt has been seen in less than two hours. From their being subject to such changes, it is inferred that they do not adhere to the body of Jupiter, but exist in his atmosphere.

This planet, even on the most careless view through a good telescope, appears to be oval, the longer diameter being parallel to the direction of the belts.

Professor Struve of Dorpat, by the most accurate admeasurements, has determined the proportion between the greatest and least diameters to be as 1,371, to 1,000.

Jupiter's Satellites.

This planet has *four satellites* revolving about him at different distances, and in different periods of time; the nearest making a revolution in less than two days, and the most distant in little more than sixteen: hence their relative situation changes every instant. Consequently, these satellites, like our moon, are subject to be eclipsed, and their eclipses are of considerable importance to astronomers. They were first discovered by Galileo in 1610.

Galileo took them, at first, for telescopic stars; but farther observation convinced him and others that they were planetary bodies. The periodical time of the first satellite is in about one day and 18 hours, the second in 3 days 13 hours, the third in 7 days 3 hours; and the fourth in 16 days 16 hours.

The angles under which the satellites appear at the mean distance of the planet from the earth, have been determined with great precision by Struve, to be first, 1,018″, second 0,914″, third 1,492″, fourth 1,277″. These numbers represent also the proportions of the diameters of the satellites. It hence appears, that the second is the smallest, the third the largest, and the fourth larger than the first.

By means of the eclipses of Jupiter's satellites, a method has been obtained for determining the longitude of places, with facility and some accuracy; and also for demonstrating that the motion of light is progressive, and not instantaneous as was once supposed.

The *velocity of light* is more than a million of times greater than of a ball issuing from a cannon. Rays of light come from the sun to the earth in less than 8 minutes; which is at the rate of about 12,000,000 of miles in a minute.

CHAPTER VII.

SATURN.*

SATURN till of late years was esteemed the sixth and the most remote planet of the solar system. He shines with a pale dead leaden light. His mean distance from the sun is about 9½ times farther off than that of the earth, being nearly 900,000,000 of miles. Of course the light and heat he derives from the sun, are about 90 times less than at the earth.

It has been calculated, however, that the light of the sun at Saturn is 500 times greater than that which we enjoy from our full moon. While our day-light is calculated to exceed that of our full moon 90,000 times.

The diameter of Saturn is nearly 80,000 miles, and his magnitude almost a thousand times that of the earth. He performs his revolution in his orbit round the sun in less than 30 of our years (10,759 days,) consequently he must travel nearly 21,000 miles an hour. He revolves about his axis in 12 hours and 13¼ minutes.

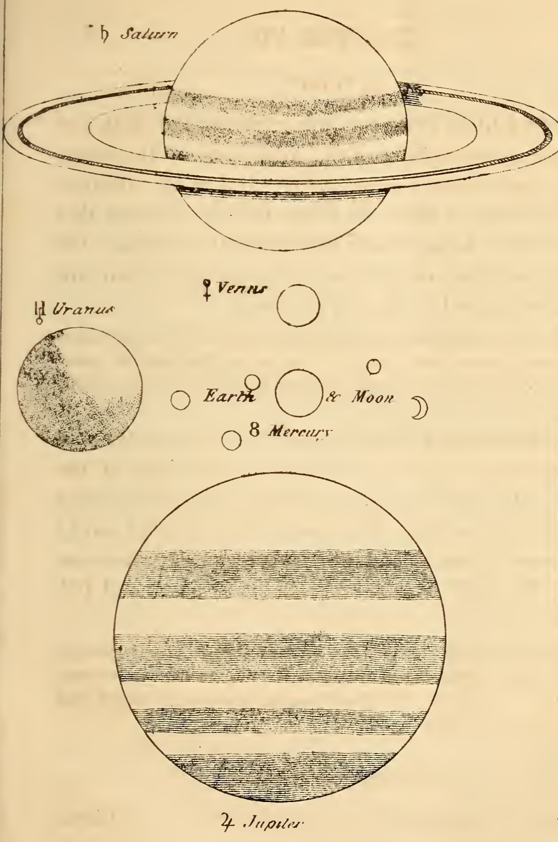
Cassini and others attempted, but without success, to determine the rotation of Saturn about his axis; but Dr. Herschel's observations have at length ascertained it. The Phil. Trans. of 1794 say $10^h\ 16'\ 0''4$; but later accounts say $12^h\ 13\frac{1}{4}'$.

SATELLITES OF SATURN.

SATURN is attended by seven Satellites or Moons, whose periodical times differ very much. The one nearest to him performs a revolution round the primary

* This name is given to the supposed father of the Heathen gods

Relative Sizes of the Planets.



planet in 22 hours and a half; and that which is most remote takes 79 days 7 hours.

The last Satellite is known to turn on its axis, and in its rotation to be subject to the same law which our moon obeys; that is, it revolves on its axis in the same time in which it revolves about the planet.

Saturn's Ring.

Saturn is also encompassed with a kind of *Ring*, or, according to Dr. Herschel, with two concentric rings, situated in one plane, which is not much inclined to the equator of the planet. They may probably be of considerable use in reflecting the light of the sun to him. See plate.

From numerous observations it has been concluded, that the nearest is 21,000 miles distant from Saturn, and that the breadth of the inner ring is 20,000 miles; that of the outer ring 7,200 miles; and the vacant space between the two rings 2,839 miles.

Dr. Herschel conjectures that it is no less solid than the planet itself; and he has found that it casts a strong shadow upon the planet. The light of the ring he has observed brighter than that of the planet; for the ring appears sufficiently bright for observation at times, when the telescope scarcely affords light enough to give a fair view of Saturn.

Professor Struve has made some interesting observations on this planet, with a superb refracting telescope.—The results of his admeasurements are, that at the mean distance of the planet,

The external diameter of the external ring is	40″.215
The internal diameter of the external ring is	35.395
The external diameter of the internal ring is	34.579
The internal diameter of the internal ring is	26.748
The equatorial diameter of Saturn is . .	18.045
The breadth of the external ring is . . .	2.410
The breadth of the chasm between the rings is	0.408

The breadth of the internal ring is 3.915
The distance of the ring from Saturn is . . 4.352

He adds, "it is remarkable that the outer ring is much less brilliant than the inner. The inner one too, towards the planet, seems less distinctly marked, and to grow fainter; so that I am inclined to think that the inner edge is less regular than the others."

The *Ring* has a rotation about its axis, or, which is the same thing, revolves about the planet, in the same time that Saturn turns round on his axis.

CHAPTER VIII.

URANUS, OR HERSCHEL.

This is the most remote planet yet discovered in our Solar system. He appears of a bluish white colour, and can rarely be seen but by means of a telescope.

He may be best perceived, by the naked eye, in a very clear night when the moon is absent.

To Dr. Herschel the world is indebted for the discovery of this planet, on the 13th of March, 1781. The Doctor, in honour of George III. king of England, named it the Georgium Sidus, (or Georgian Star,) though by astronomers it is called the Herschel, in testimony of respect to the discoverer. American astronomers call it Uranus.

The *distance* of this planet from the sun is more than 1,800,000,000 miles; or about nineteen times that of the earth.

The distance given by some authors, is 1,812,000,000 miles. The light and heat which he derives from the sun, are supposed to be about the 361st part of those at our earth (for the square of 19 is 361; which see explained in a future chapter)—that is, about equal to the effect of 249 of our full moons.

He performs his *annual revolution* in 3,069 days, or about 84 of our years; consequently he must travel at the rate of 16,000 miles an hour.

The time of his completing a revolution has been ascertained by a series of observations. When first discovered in March 1781, he was in Gemini: and in August 1803, he had advanced to 11° of Libra; or through more than a fourth part of his orbit.

His *diameter* is found to be 35;865 English miles; but his *diurnal rotation* has not yet been discovered.

The Herschel's Satellites.

The Herschel, or Uranus has *six Satellites;* the one nearest the planet performs his revolution round the primary in less than six days; and that which is the most remote in rather more than 107 days and a half.

Though the light of these Satellites or Moons is, as Dr. Herschel observes, extremely faint, yet they are, probably, of great benefit to the inhabitants of that planet; for it is reasonable to conclude that there is scarcely any part of his orb but what is constantly enlightened by one or other of them.

The proportional Magnitude and Distance of the Planets.

The Earth is fourteen times as large as Mercury;—very little larger than Venus;—three times as large as Mars; more than a million times as large as Pallas. But Jupiter is more than fourteen hundred times as large as the Earth. Saturn above a thousand times as large, exclusive of his ring; and the Georgian eighty times as large.

As the distances of the planets when given in miles, are such a burthen to the memory as seldom to be retained, astronomers often express their mean distances in a shorter way, by supposing the distance of the earth from the sun to be divided into *ten* parts. Mercury may then be estimated at *nearly four* of such parts from the sun. Venus at *seven*, the Earth at *ten*, Mars at full *fifteen*, Jupiter at *fifty-two*; Saturn at *ninety-five*, and the Georgian one hundred and ninety parts. [See the scale on the frontispiece.] These are calculated by multiplying the respective distances of the planets by 10. and dividing by 95, the mean distance of the earth from the sun. For the relative magnitudes of the planets see plate 3.

CHAPTER IX.

COMETS.

Comets, like the orbs already mentioned, are supposed to be planetary bodies forming a part of our system; for, like the planets, they revolve round the sun; not, indeed, in orbits nearly circular, but in very different directions, and in extremely long elliptic curves, having the sun in one of their *foci*; approaching sometimes near the sun, at others stretching far beyond the orbit of the remotest planet. The periods of their revolutions are so long that only three are known with any degree of certainty.

Some suppose them not adapted for the habitation of animated beings, on account of the great extremes of heat and cold, to which, in their course, they appear to be subject.

The name of Comet is derived from *Cometa*, "hairy;" because Comets appear with long tails, somewhat resembling hair. This appearance is supposed to be nothing more than vapour arising from the body in a line opposite to the sun; some indeed have been seen without such appendage, and as round as the regular planets. The knowledge, however, which we have of Comets, is very imperfect, as they afford but few observations on which to ground conjecture.

By common people they are called *blazing stars*, and by some they are thought to be portentous; presaging some extraordinary event. But they can have no such tendency, nor can there be any apprehension that they can injure the earth we inhabit, by coming into contact. Even the tail of the Comet cannot come near our atmosphere, unless it should be at its inferior conjunction very nearly at the time when it is in its node; circumstances so extremely unlikely, that there are some millions to one against such a conjunction.

It was thought that the periods of three of the Comets had been distinctly ascertained; the first of these appeared in 1531, 1607, and 1682, and it was expected to return every 75th year; and one did appear in 1758, which was supposed to be the same.

The second of them appeared in 1532 and 1661, and was again expected in 1789, but in this the astronomers were disappointed.

The third was that which appeared in 1680, and its period being estimated at 575 years, cannot, upon that supposition, return till 2255. This Comet, at its *greatest* distance, is 11,200,000,000 of miles from the sun; and its *least* distance from the sun's centre was but 490,000 miles; in this part of its orbit it travelled at the rate of 880,000 miles in an hour.

Comets differ much in their magnitude, though most of those which have been observed are less than the moon; but their dimensions are not determined with accuracy.

The head of the Comet of 1807 was ascertained to be about 538 miles in diameter; and that of 1811, about the size of the moon.

According to Sir Isaac Newton, comets are of an opaque nature, and consist of a very compact, durable, and solid substance, capable of bearing exceedingly great degrees of heat and cold. The Comet seen by him in 1680, was observed to approach so near the sun that its heat was estimated by him to be 2,000 times greater than that of red hot iron. And it has been said that a globe of red hot iron as large as our globe would scarcely cool in 50,000 years.

Notwithstanding the above supposition the appearance of the two brilliant Comets, of late, seems to overturn that theory. Of that in 1807, Dr. Herschel says, we are authorized to conclude that the body of the Comet, on its surface is *self luminous*, from whatever cause this quality may be derived. The vivacity of the light of the Comet, also, had a much greater resemblance to the radiance of a star, than to the mild reflection of the sun's beams upon the moon.

Comets consist (according to modern observation) of the nucleus, the head, the coma, and the tail. The *nucleus* is a small and brilliant part in the centre; the *head* includes all the very bright surrounding light; the *coma* is the hairy appearance surrounding the head; and the *tail*, which is of great length, is supposed to consist of radiant matter, such as that of the aurora borealis.

The tail of the Comet in 1807, was ascertained to be more than 9,000,000 of miles in length; and that in 1811, to be full 23,000,000 in length. The distance of this Comet from the sun was 95,000,000 of miles, and from the earth upwards of 142,000,000 of miles.

CHAPTER X.

THE FIXED STARS.

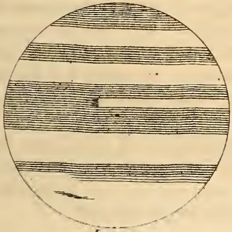
All the heavenly bodies beyond our system are called *Fixed Stars*, because, except some few, they never appear to move or to change their places, with regard to each other, as the planets do. As they are placed at immense distances from our system, they must be bodies of great magnitude, and doubtless shine by their own light. They are probably suns, like our sun, to different systems of planets: each fixed star being supposed to be the centre of its own system.

That the fixed stars shine by their own light is concluded; being at such vast distances from the sun, they could not possibly receive from him so strong a light as they shine with. So great is their distance

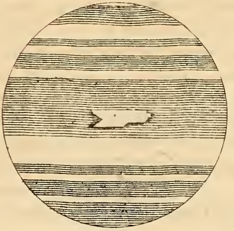
Telescopic Views.

Jupiter.

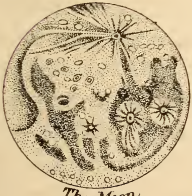
Jupiter.



Jupiter.

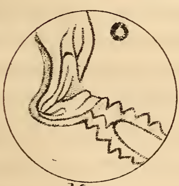


Jupiter.



The Moon.

Mars.



Mars.

Mars.

P. S. Duval's Lith. Phil^a

[illegible]

that though the orbit of the earth is twice 95,000,000 of miles across, and we are consequently 190,000,000 of miles nearer to some stars at one time than we are at another, yet the stars always appear in the same places, and with the same magnitude. See plate IV. fig. 2. Let * * * represent the fixed stars, and A B C D, the earth's annual course; then will the earth in that part of its orbit at B, be 190,000,000 of miles nearer to the fixed stars, than when at D.

The distance of Sirius, or the Dog-star, the nearest of the fixed stars, cannot be less than two millions of millions of miles. A cannon ball flying from that star at the rate of 400 miles an hour, would not reach us in 570,000 years.

Professor Vince says, "the nearest fixed star cannot be less than 400,000 times farther from us than the sun is." Hence 400,000, multiplied by 95,000,000, give 38 millions of millions of miles for the nearest fixed star.

Dr. Herschel says, that several of the fixed stars revolve on their axes.

The fixed stars, then, are most probably suns, which, like our sun, serve to enlighten, warm, and sustain other systems of planets, and their dependent satellites.

They are usually classed into six magnitudes, which include all that can be seen without a telescope; the largest are called stars of the first magnitude, and the smallest, those of the sixth. There are seldom so many as a thousand visible at one time, to the naked eye, even in a clear star-light night.

The number of stars appears to us at times innumerable; but this is a deception, occasioned from their being observed by us in a confused manner, or by the refraction and reflection of the rays of light, passing from them through our atmosphere.

Many of the fixed stars, which to the naked eye appear as *single stars*, are found to consist of two, and some even of three, or more.—Not that they are really double or treble, but they are stars at different distances, which appear nearly in a right line. There are also clusters of stars, called *nebulæ:* the most remarkable of these is, that broad zone, called the Milky way. In this bright track, Dr. Herschel has seen 116,000 stars pass over the field of his telescope, in a quarter of an hour.

The Magellanic clouds, near the south pole, which resemble two whitish spots in the heavens, are of the order of *nebulæ,* and are well known to sailors.

Since the introduction of telescopes, the number of fixed stars has been considered as immense; and by the greater perfection of our glasses, still more stars are discovered; so that there appear to be no bounds to their number, or to the extent of the universe.

There are two methods of discovering which are planets, and which are fixed stars: the first is by their twinkling or not; for every fixed star *twinkles,* but a planet does not. The second is by the nature of their motions: they all, indeed, appear to rise and set; but, besides that, the planets have a motion from one part of the heavens to another, sometimes among the fixed stars in one constellation, at other times among those of another; whereas the fixed stars keep constantly the same relative distance from each other.

Many conjectures have been offered as to the *cause* of the *twinkling* of the fixed stars; perhaps it may be the unequal refraction of light, in consequence of inequalities and undulations in the atmosphere.

Several stars mentioned by ancient astronomers are not now to be found, and several are now observed which do not appear in their catalogues.

The most ancient observations of a *new star* is that by Hipparchus, about 120 years before Christ. Some others have been noticed in later times; but the first new star we have any accurate account of, is that which was discovered by Cornelius Gemma, in 1572, in the Chair of Cassiopeia. It exceeded Sirius in brightness, and was seen at mid-day. It first appeared larger than Jupiter, but it gradually decayed; after sixteen months it entirely disappeared.

Some fixed stars have been noticed alternately to appear and disappear, and others have been subject to great periodical variations in their magnitudes.

In 1600, a *changeable* star was discovered by W. Jansenius, in the neck of the Swan, which appeared visible for many years; but from 1640 to 1650 was invisible. It was seen again in 1655, increased till 1660, then grew less, and disappeared. In 1665 re-appeared; disappeared in 1681. In 1715, it appeared of the sixth magnitude, as it is seen at present.

To mention one more instance, among many, β *Lyræ* was discovered by Mr. Goodrich, to be subject to a *periodic variation.* It completes all its phases in 12 days, 19 hours, during which time it undergoes the following changes: 1. It is of the third magnitude for about two days. 2. It diminishes in about 1¼ day. 3. It is between the fourth and fifth magnitude for less than a day. 4. It increases in about two days. 5. It is of the third magnitude for about 3 days. 6. It diminishes in about one day. 7. It is something larger than the fourth magnitude for a little less than a day. 8. It increases in about one day and three quarters to the first point, and so completes a whole period. See Phil. Trans. 1785.

In whatever part of the universe we are, *we appear to be in the centre of a concave;* that is, a hollow sphere, where all remote objects appear at equal distances from us; so that, whether we are on the planet Venus, or on the earth, or on any planet or star in the universe, the effect in this particular would be the same.

As a proof of this, the sun, moon, and stars, appear at *equal* distances; whereas the sun (as has been mentioned) is 400 times farther off than the moon, and the fixed stars at least 200,000 times farther from us than the sun.

If transplanted to a planet of any other system, suppose to one belonging to Sirius; then Sirius, which now appears only as a star, would prove a sun. Our sun would then appear as a star, and the earth, with all the other planets, would be invisible.

The vulgar error, that all these stars were placed in the heavens only to afford us light, must be erroneous, since thousands of them are invisible to us without the help of a telescope, and we receive more light from the moon, than from all the stars together.

CHAPTER XI.

CONSTELLATIONS.

THE ancients, in reducing astronomy to a science, formed the fixed stars into constellations, or collections of stars, and represented them by animals, and other figures, according to the ideas which the dispositions of the stars suggested.

This arrangement took place very early; for some kind of division must have been suggested by necessity, in order that astronomers might describe any particular star so as to be understood. Neither, without some such division, could the situation of the planets have been pointed out, as they are continually changing their places. We find mention made of Orion and Pleiades by Job. Homer and Hesiod also make mention of some of them; but Aratus enumerates almost all the ancient ones.

The number of the ancient constellations was about fifty, but the present number upon the globe is eighty.

The heavens are usually distinguished by *three regions*, called the *Northern* and *Southern* hemispheres, and the *Zodiac*. The number of the constellations, in the northern hemisphere, is 36; in the southern, 32; and in the zodiac, 12. Stars not comprehended in any of these, are called *unformed stars*.

Northern Constellations.

	Number of Stars
Ursa Minor. The Little Bear	24
Draco. The Dragon	80
Cepheus	35
Lacerta. The Lizard	16
Cassiopeia. The Lady in her Chair	55
Perseus	59
Caput Medusæ. Medusa's Head	
Camelopardalus. The Camelopard	58
Lynx. The Lynx	44
Ursa Major. The Great Bear	87
Cor Caroli. Charles's Heart	
Leo Minor. The little Lion	53
Coma Berenices. Berenice's Hair	43
Asterion and Chara. The Greyhound	25
Boötes	54
Corona Borealis. The Northern Crown	21
Hercules. Hercules kneeling	13
Cerberus. The Three Headed Dog	9
Lyra. The Harp	21
Cygnus. The Swan	81
Velpecula et Anser. The Fox and Goose	35
Sagitta. The Arrow	18
Delphinus. The Dolphin	18
Pegasus. The Flying Horse	89
Andromeda	66
Triangulum Boreale. The Northern Triangle	16
Musca. The Fly	
Auriga. The Wagonner	66
Mons Mænalus The Hill Mænalus	

	NUMBER OF STARS
Serpens. The Serpent	64
Serpentarius. The Serpent Bearer	74
Scutum Sobieski. Sobieski's Shield	8
Taurus Poniatowski. Poniatowski's Bull	
Antinoüs	34
Aquila. The Eagle	12
Equulus. The Colt	10

The Southern Constellations.

Piscis Australis. The Southern Fish	24
Cetus. The Whale	97
Eridanus. The River Po	84
Orion	78
Lepus. The Hare	19
Canis Major. The Great Dog	31
Monoceros. The Unicorn	39
Canis Minor. The Little Dog	14
Hydra. The Hydra	60
Sextans. The Sextant	41
Crater. The Cup	31
Corvus. The Crow	9
Argo Navis. The Ship Argo	64
Crux. The Cross	
Centaurus. The Centaur	35
Lupus. The Wolf	24
Ara. The Altar	9
Corona Australis. The Southern Crown	12
Columba Noachi. Noah's Dove	10
Robur Carolinum. The Royal Oak	12
Apis. The Bee	4

Fig. 1.

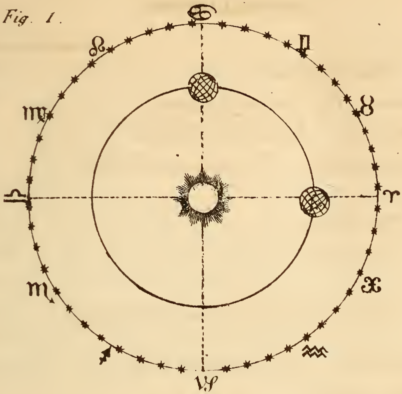
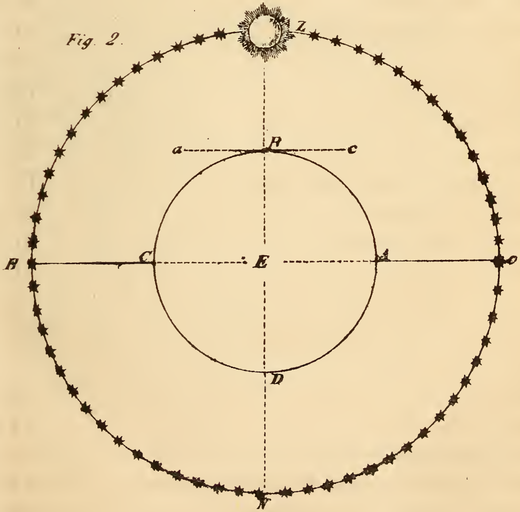


Fig. 2.



	NUMBER OF STARS.
Triangulum Australe. The South Triangle . .	5
Apus. The Bird of Paradise	11
Pavo. The Peacock	14
Indus. The Indian	12
Grus. The Crane	13
Phœnix. The Phœnix	14
Toucon. The American Goose	9
Hydrus. The Water Snake	10
Dorado. The Sword Fish	6
Piscis Volans. The Flying Fish	8
Chamæleon. The Cameleon	10

The Zodiacal Constellations.

Aries. The Ram.	66
Taurus. The Bull	141
Gemini. The Twins	85
Cancer. The Crab	83
Leo. The Lion	95
Virgo. The Virgin	110
Libra. The Balance	51
Scorpio. The Scorpion	44
Sagittarius. The Archer	69
Capricornus. The Goat	51
Aquarius. The Waterman	108
Pisces. The fishes	113

Some of the principal fixed stars are distinguished by particular names, as Regulus, Arcturus, Sirius, &c., others are denoted by the letters of the Greek alphabet, the first letter being put to the greatest star in each constellation; the second letter to the next greatest, and so on; and when any more letters are wanted, the Italic letters are generally used.

By this contrivance the place of any particular star in the heavens may be found, with the greatest ease and precision.

CHAPTER XII.

DIFFERENT SYSTEMS.

The system we have been describing, and which is now universally received, is called the Copernican. It was formerly taught by Pythagoras, a Greek philosopher, born in the island of Samos, 590 years before Christ, and Philolaüs, his disciple, finding it impossible any other way to give a consistent account of the heavenly motions.

This system, however, was so extremely opposite to all the prejudices of sense and opinion, that it never made any great progress in the ancient world till revived by Copernicus.

Ptolemy, an Egyptian philosopher, who flourished 130 years after Christ, supposed at first that the earth was perfectly at rest near the centre; and that all the other bodies, namely, the sun, moon, planets, comets and fixed stars, revolved about it in circles every day. But as their retrograde motions and stationary appearances could not thus be solved, he afterwards supposed them to revolve in epicycloids.

Epicycloids are curves generated by the revolution of the periphery of a circle along the concave or convex parts of another circle.

The full illustration of this motion may exceed the present comprehension of the learner, but he may conceive it to be not much unlike the curve line, *a, b, c, d, e, f*, &c., plate XV. fig. 1. Now it is evident that at the points *b* and *c*, and also *d* and *e*, the planet's motion would appear *stationary* and *retrograde* from *b* to *c*, and from *d* to *e*, and at other times *direct*.

But though this system will not solve the phases of Venus and Mercury, and for other reasons cannot be true, it was maintained from the time of Ptolemy till the revival of learning in the sixteenth century.

The Egyptians received also the following system:—That the earth is immoveable in the centre, about which revolve, in order, the Moon, Sun, Mars, Jupiter and Saturn; and about the sun, revolve Mercury and Venus. This disposition will account for the phases of Mercury and Venus, but not for the apparent motions of Mars, Jupiter, and Saturn.

At length Copernicus, a native of Poland, adopted the Pythagorean system, and published it to the world in 1530. This doctrine had been so long in obscurity, that the restorer of it was considered the inventor.

Copernicus placed the Sun in the centre of the system, and about it, the other bodies in the following order: Mercury, Venus, the Earth, Mars, Jupiter and Saturn.

Europe, however, was still immersed in ignorance, and the general ideas of the world were not able to keep pace with those of a refined philosophy. This occasioned Copernicus to have few abettors, but many opponents.

Tycho Brahe, a noble Dane, and eminent philosopher, sensible of the defects of the Ptolemaic system but unwilling to acknowledge the motion of the earth, endeavoured, about 1586, to establish a new system of his own, in which the earth was supposed the centre of the sun and moon; that Mercury, Venus, &c. revolved about the sun, and that the sun and planets, together, turned round the earth in 24 hours. But as this proved to be still more absurd than that of Ptolemy, it was soon exploded, and gave way to the Copernican, or true solar system.

Some of Tycho's followers, seeing the absurdity of supposing all the heavenly bodies daily to revolve about the earth, allowed a rotary motion to the earth, in order to account for their diurnal motion, and this was called the Semi-Tychonic system.

Thus the solar system, now adopted, after having been taught by Pythagoras, and revived by Copernicus, was confirmed by Galileo, Kepler, and Descartes, and fully established by Sir Isaac Newton. See Planetarium, plate 6.

CHAPTER XIII.

OF THE MOTIONS OF THE PLANETS:

DIRECT, STATIONARY, AND RETROGRADE.

THE planets, Mercury, Venus, the Earth, &c. if seen from the sun, would appear to pass from star to star, through the constellations, in a uniform and regular manner.

But as seen from the earth, they apparently move very irregularly; sometimes they appear to go *forward*, at other times to remain *stationary*, and then to *recede*.

To give some idea of this, suppose yourself placed *in the centre* of a circular course, keeping your eye on the horse while going round; it is evident that he would appear to run round the whole course in a *regular* manner. Again; imagine yourself placed at a considerable distance on the *outside* of the course, and the horse's motions would appear no longer uniform. On the *opposite* side of the course alone would he seem regular: then alone would it appear the same as when you stood in the centre. When he *approached* you, he would scarcely seem to move; in that part of his course *next* to you, he would move in a direction *contrary* to what he did at first; and again, when going from you, his motion would be scarcely visible.

When the planets are *farthest* from us, their motion is said to be *direct;* when *nearest* to us *retrograde*, because they appear to be moving back again; and when either *approaching* us, or going *from us*, we say they are *stationary*, because, if then observed in a line with any particular star, they will continue so for a considerable time; now these appearances could not happen if they moved round the earth as their centre. See plate VII. fig. 1.

Inferior and Superior Conjunctions of the PLANETS.

WHEN Mercury or Venus is nearest to us, that is, in a line between us and the sun (see plate VII. fig. 2.) we say it is in *inferior* conjunction; when farthest from us, and the sun is between us and the planet, in *superior* conjunction.

The *superior* planets, namely, those whose orbits include that of the earth, have alternately a *conjunction* and an *opposition;* a *conjunction*, when the sun is between the earth and the planet; and an *opposition*, when the *earth* is between the sun and the planet, that is, when the planet is nearest to us, and appears to be opposite to the sun.

Hence, when a planet is in *conjunction*, it rises and sets nearly *with* the sun; but in *opposition*, it *rises* nearly when the *sun sets*, and *sets* when he *rises*.

We say *nearly*, because it cannot be exactly, except when the planet is in or near its node; or, which is the same thing, when the sun, earth and planet, are in a *right line*, which seldom happens.

As only that side of a planet which is turned to the sun can be enlightened by him it is evident, that as viewed with a telescope from the earth, its appearance must vary; thus *Venus*, just before and after her *superior* conjunction, would be seen nearly with *a full face*, when stationary, she would appear only *half* enlightened, like the moon at the first quarter, because an equal portion of the bright and dark sides will be turned towards us; the bright parts will be decreasing till her inferior conjunction, and then only the dark side will be turned towards us, and consequently she will be for a short time *invisible:* by-and-by she will become again stationary, and appear like the moon at her third quarter.

It is true, both Mercury and Venus may at times be seen even when in their inferior conjunctions, but it can be only in their *transits*, which will be explained in a future chapter.

These appearances refer to the *inferior* planets *only*, Mercury and Venus. The superior planets always appear with nearly a full face.

CHAPTER XIV.

THE PLANE OF AN ORBIT, PLANETS, NODES, ETC.

The earth, as seen from the sun in its periodical revolution, will describe a circle among the stars, which astronomers call the *ecliptic;* and sometimes the *sun's* *annual path*, because the sun, as seen from the earth, always appears in that line.

Suppose the earth, if seen from the sun, to appear in *Cancer*, then the sun, if viewed from the earth, will appear in *Capricorn*; or, if the earth appear in *Aries*, the sun will appear in *Libra*. See plate IV. fig. 1.

By the *plane of a circle* may be understood that supposed surface which would lie evenly between every part of the circumference.

Any flat and smooth surface is a *plane*; hence the *edge* of a round table may represent the *ecliptic*, and the *surface* of the table its *plane*.

Though the orbit of the earth and the ecliptic are in the same plane, they are not the same thing; for the ecliptic is supposed to extend far beyond that of the earth to the fixed stars.

If the edge of a round table be made to represent the ecliptic, then a circle within, drawn from the centre of the table, may represent the orbit of the earth, and they will be both in the same plane, though of unequal dimensions.

The orbits of the planets are not in the same plane as that of the earth; in other words, the planets do not move in the ecliptic. They are in every revolution one-half of their periods a little *above* the ecliptic, and the other half as much *below* it. This is called the *inclination* of their orbits (see plate VIII. fig. 1.) where S represents the sun; A B C D the orbit of the earth; and E F G H the orbit of one of the inferior planets, suppose of Venus; the half, F G H, rises *above*, and the other half, H E F, sinks below it, from the points H F, which are in a line with the orbit of the earth.

The dotted line *b* H F *a*, is called the *line of the nodes;* and the points H F, the *nodes* of the planet. The point F is called the *ascending* node, because the planet is then ascending or rising *above* the orbit of the earth; or, which is the same thing, above the ecliptic. When in H it is descending below it, whence that point is called the *descending node*.

As the planes of the planets' orbits vary a little from each other, so their nodes or intersections are at different parts of the plane of the ecliptic.

The dotted line, *c d e f*, may represent the orbit of any other planet, and convey some faint idea of the way in which they intersect each other.

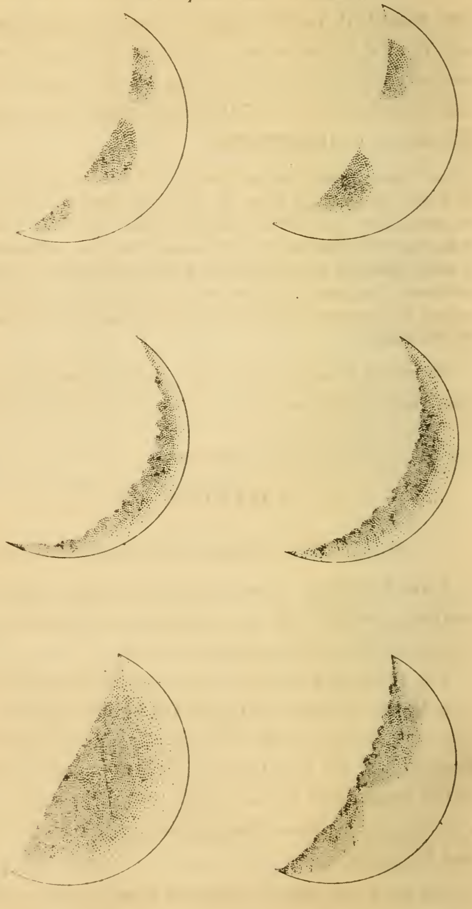
Not that we are to suppose, when speaking of the *plane* of the ecliptic, or plane of the earth's orbit, that it is a real and visible flat surface; nor in speaking of the *orbits* of the planets, that we mean solid rings; for the planets perform their revolutions with the utmost regularity in unbounded space.

The Transits of Mercury *and* Venus.

If Venus were in her *ascending* node at F, (plate VIII. fig. 1,) when the earth is at *a*, or in her descending node at H, when the earth is at *b*, she would be in a line with the sun, and on the sun's disc she would appear a *dark round spot* passing over it. These appearances are called *transits;* they happen very seldom, because Venus is very seldom in or near her nodes at her inferior conjunctions.

That there are *great variations in the apparent diameter of Venus* may be demonstrated thus: suppose S (plate VII. fig. 1.) to be the sun, E the earth in its orbit, and *a b c d*, &c. Venus in her's: now it is evident that when Venus is at *a* between the sun and earth

Telescopic Views of Venus



she would, if visible, appear much larger than when she is at *e* in superior conjunction, because so much nearer in the former case than in the latter; being in the situation *a*, but 27,000,000 miles from the earth E; but at *e*, 163,000,000.

As Venus passes from *a* through *b c d* to *e*, she may be observed by a good telescope to have all the same phrases as the moon has in passing from new to full; therefore when she is at *e* she is full. Also, during her journey from *c* through *f* to *g*, she will appear to have a *direct* motion in her orbit; from *g* to *h*, and from *b* to *c* to be nearly *stationary*, but from *h* to *b*, her motion, though still really direct, will appear to a spectator at E, to be going back again, or *retrograde*, as was shown before.

Mercury is seen in the same manner, which is a proof that their orbits must be *within* that of the earth.

CHAPTER XV.

THE ECLIPTIC, ZODIAC, AND EQUATOR, ETC.

The Ecliptic is an imaginary great circle in the heavens, which the sun *appears* to describe in the course of the year, among the stars.

The following are the most conspicuous stars that lie near to the ecliptic:—The Ram's Horn, called, α Arietis—Aldebaran, in the Bull's Eye—Castor and Pollux—Regulus, or the Cor Leonis—Spica Virginis—Antares, or the Scorpion's Heart—also, which lie more distant, α Altair, in Aquila—Fomaehaut, in the Fish's Mouth, and Pegasus.

The above nine stars are considered as the most conspicuous near the moon's orbit—from these the moon's distance is calculated, and hence the tables in the *Nautical Almanac* are constructed for the use of navigators. The Ecliptic is so called, because all the eclipses must necessarily happen in this line, where the sun always is.

The Ecliptic and Equator, being great circles, must bisect, or equally divide each other; and their inclination is called the obliquity of the Ecliptic. Also the points where they intersect are called the *equinoctial points*, and the times when the sun comes to these points are called the *equinoxes*.

The ZODIAC is an imaginary broad circle, or belt, surrounding the heavens, extending about 8° on each side the ecliptic, in which the planets, with the exception of Ceres, Pallas, and Juno, constantly revolve.

The term *Zodiac* is derived from a Greek word ζωδιακος; from ζωον, "an animal," because each of the twelve signs formerly represented some animal; that which we now call Libra being by the ancients reckoned a part of Scorpio.

For the definitions of degrees, &c. see preliminary definitions.

The names and characters of the twelve signs, with the time of the sun's entrance into them, are as follow:

1. Aries, ♈, or the Ram; March 20th.
2. Taurus ♉, the Bull; April 20th.
3. Gemini, ♊, the Twins; May 21st
4. Cancer, ♋, the Crab; June 21st.
5. Leo, ♌, the Lion; July 23d.
6. Virgo, ♍, the Virgin; August 23d.
7. Libra, ♎, the Balance; September 23d.
8. Scorpio, ♏, the Scorpion; October 23d.
9. Sagittarius, ♐, the Archer; November 22d
10. Capricornus, ♑, the Goat; December 21st
11. Aquarius, ♒, the Waterman; January 20th.
12. Pisces, ♓, the Fishes; February 19th.

Dr. Watt's lines, "The Ram, the Bull," &c. are well known; but, perhaps, to learn the signs in the *above* order will answer a better purpose, and be but little extra labour.

The order of these is according to the motion of the sun. The *first point of Aries* coincides with one of the equinoctial points, and the *first point of Libra* with the other.

The first six are called *northern* signs, lying on the north side of the equator; and the last six *southern*, lying on the south side.

The signs ♑, ♒, ♓, ♈, ♉, ♊, are called *ascending*, because the sun approaches our north pole while it passes through them; and ♋, ♌, ♍, ♎, ♏, ♐, are called *descending*, the sun receding from our pole as it passes through them.

Each of the 12 signs of the Zodiac contains 30 degrees.

The EQUATOR is either *terrestial* or *celestial.*

The *terrestial Equator* is an imaginary great circle of the earth, perpendicular to its axis; hence the axis and poles of the earth are the axis and poles of the equator. This circle is equally distant from the two poles, and separates the globe into the northern and southern hemispheres.

The *celestial Equator*, called also the *equinoctial*, is a plane of the terrestial equator *extended to the fixed stars*; and if the axis of the earth be produced in like manner, they will be the *poles* of the celestial equator. And the star nearest to the north pole is called the *pole star*, as P. P. fig. 2, plate II.

OF THE EPHEMERIS.

The Astronomical Ephemeris being frequently alluded to in the use of the globes and the study of astronomy, a short explanation of the astronomical part of the only work of this kind published in this country, viz. the American Almanac, may be acceptable, taking, for example, that for the current year, 1832.

The first thirty-five pages, which are occupied by the relations of the planets, the time of the entrance of the Sun into the signs of the Zodiac, the length of each of the four seasons, the calendars of the Jews and Mahometans, the eclipses of the Sun, Moon, and satellites of Jupiter ; the occultations of the fixed stars by the moon, the elements of the two comets of short period, known as Encke's and Biela's : the position and magnitude of the rings of Saturn, the aspects of the planets, the height of the greatest tides, the usual height of the spring tides at several places on the American coast, the difference between the time of high water at these places and at Boston, the latitude and longitude of most of the principal places in the United States, and with the length of the longest and shortest days thereat, will, it is supposed, require no illustration.

Of the calendar pages, those (36 and 37) for the month of January may be taken as an example. On the top of the left hand page will be found the apparent time of the beginning and end of twilight, or the time when the Sun is 18 degrees below the horizon before sunrise, and after sunset, for every sixth day, at Boston, New York, Washington, Charleston, and New Orleans; which places being situated in different latitudes, renders the almanac equally useful to every part of the United States. It may however be proper to remark, that the twilight will not in general be sufficiently strong to be visible, unless the Sun is considerably less than 18 degrees below the horizon. On the 1st of January it appears that the twilight begins at New Orleans at 27 minutes after 5 in the morning, and ends at 27 minutes before 7 in the evening. Under the above, will be found the time of the Moon's apogee and perigee, or the time in each lunation, when

Fig. 1.

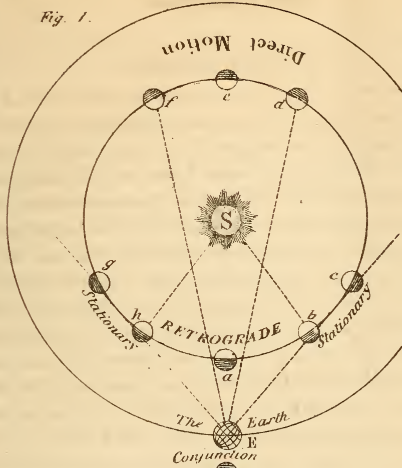
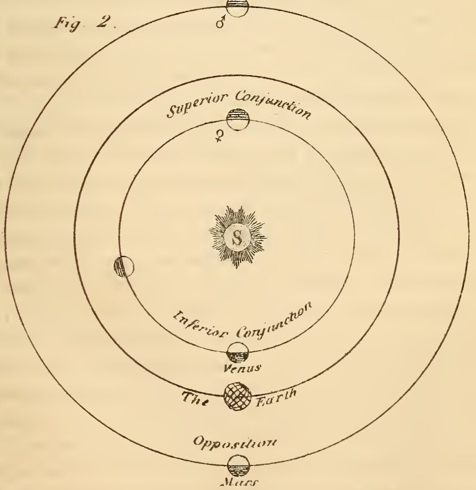

Direct Motion
f
e
d
S
g
c
Stationary
h
b
RETROGRADE
Stationary
a
The Earth
E
Conjunction

Fig. 2.


♂
Superior Conjunction
♀
S
Inferior Conjunction
Venus
The Earth
Opposition
Mars

she is farthest from, and nearest to the Earth, with the distance between the Earth and Moon, at those times, in English miles.

Next below are placed the phases of the Moon, or the mean time at Washington of her conjunction, quadratures, and oppositions with the Sun: under these are placed the columns of the calendar, viz. the day of the month and the corresponding day of the week, also the apparent time of the rising and setting of the Sun, and the mean time of the rising or setting of the Moon, calculated for the same cities for which the twilight was computed: thus, on the 2d of January the Sun rises at Boston at 21 minutes after 7, and sets 31 minutes before 5; at New Orleans, he rises 57 minutes after 6, and sets 57 minutes before 6; the Moon sets the same day at Boston at 39 minutes after 4 in the afternoon, and at New Orleans 5 minutes after 5. By doubling the time of the Sun's rising we have the length of the night, and by doubling that of his setting, the length of the day; hence, at Boston on the 2d of January, the length of the day, or the interval between the rising and setting of the centre of the Sun, exclusive of the effect of refraction, is 8 hours 58 minutes, and at New Orleans 10 hours 6 minutes: want of room is the reason assigned in the almanac for expressing the beginning and end of twilight and the rising and setting of the Sun in apparent time Apparent time is, however, readily converted into mean, by applying the equation (third long column right hand page) according to the direction at the head of the column; and mean into apparent, by applying the equation contrary to the direction: thus, on the 2d of January the equation being 4 minutes to be added to apparent for mean time, and consequently to be subtracted from mean for apparent; the Sun rose that day at Boston, in mean time, at 35 minutes after 7 and sat 27 minutes before 5; and the Moon sat the same day, in apparent time, at 30 minutes after 4.

The column of the equation of time shows the quantity by which a well regulated clock is fast or slow of the Sun, and by it watches or clocks may be regulated, by comparing them with a good dial at any time when the Sun shines thereon, and examining if the difference between them agrees with the figures in this column: thus, on the first day of January 1832; a clock did not show true mean time unless it was 13 minutes 42 seconds faster than the time by the dial, or unless when the shadow indicated noon, the clock was 13 minutes 42 seconds past 12.—For further illustrations see the chapter on the equation of time, page 65.

The second long column of the right hand page gives the mean time of the daily passage of the Moon over the meridian of Washington, or the instant her centre bears down South at that place. On the day of conjunction with the Sun, the Moon the planets, and the fixed stars come to the meridian very nearly at the same moment with him; and if the conjunction takes place precisely at noon, the two bodies will be on the meridian precisely at the same time; in all other positions than when in conjunction, the Moon, planets, and stars will pass the meridian before, or after the Sun, according as the Sun's right ascension is greater or less. The mean time of the passage of any heavenly body over the meridian, is easily found by subtracting the siderial time at the moment of the passage, from the right ascension of that body at the same moment.

The fourth, fifth, and sixth of the long columns contain the mean time of high water at Boston, New York, and Charleston, of that tide which arrives when the Moon is near to the meridian. The 7th long column contains the remarkable days in the month, the conjunction of the Moon with fixed stars and planets, that may be occultations in some part of the United States, and other phenomena interesting to the astronomer. At the top of the right hand page, will be found the mean time of the passage of the planets over the meridian of Washington, with their declinations or distance from the equator at that time, on every sixth day. By the assistance of this table, the places of the planets may be easily found in a celestial globe; it being borne in mind, that north declinations are designated by the sign + and south by —.

On pages 60, 61, 62, 63, are the Sun's declination, and the siderial time, which are given for every day, at noon, at Berlin;

or about six in the morning at Washington, the former in apparent, the latter in mean time; the greatest declination (23° 27½′) will be found on the 21st of June and December: about the 20th of March, and 23d of September, the declination appears to be nothing; the Sun's centre is, therefore, then but for a single moment in the celestial equator, which is vulgarly termed crossing the line; the exact moment of the Sun having no declination, may be thus ascertained. On the 20th of March, 1832, at apparent noon at Berlin, in Prussia, it appears by the almanac, the declination of the Sun's centre was 2′ 59.2″ south, and on the 21st 20′ 41.3″ north; then by proportion as 23′ 40.5″ (the variation in 24 hours) is to 2′ 59.2″, so is 24 hours to 3 hours 1 minute 40 seconds; consequently the Sun's centre was in the celestial equator at Berlin, March 20th, 3 hours 1 minute 40 seconds apparent, or 3 hours 9 minutes 14 seconds mean time in the afternoon: from which subtracting the difference of longitude, 6 hours 1 minute 41 seconds, (Washington being west of Berlin,) we have the corresponding time at Washington, March 20th, 9 hours 7 minutes 33 seconds, mean time, in the morning.

The Sun's siderial time, is what the Sun's right ascension would be, if the Earth moved uniformly in her orbit, and in the plane of the celestial equator; it therefore is the Sun's actual right ascension, diminished or increased by the equation of time. It is of the greatest importance for the determination of the *mean* time of the passage of the Moon, planets, or stars over the meridian, by subtracting it from the right ascension of the Moon, planet, or star, at the moment of the passage. If the latter be the greater, the passage will be after; and if less, before that of the Sun. For example, the star Aldebaran will be on the meridian of Washington, August 28th, 1832, at 5 hours 59 minutes 38 seconds mean time, in the morning, its right ascension at that moment being 4 hours 26 minutes 18 seconds; and the siderial time 10 hours 26 minutes 40 seconds.

CHAPTER XVI.

A Degree is the 360th part of a circle; and the measure of an angle is an arc, or part of the circumference of a circle, whose angular point is the centre; and so many 360th parts as an arc contains, so many degrees the measure of an angle is said to be:

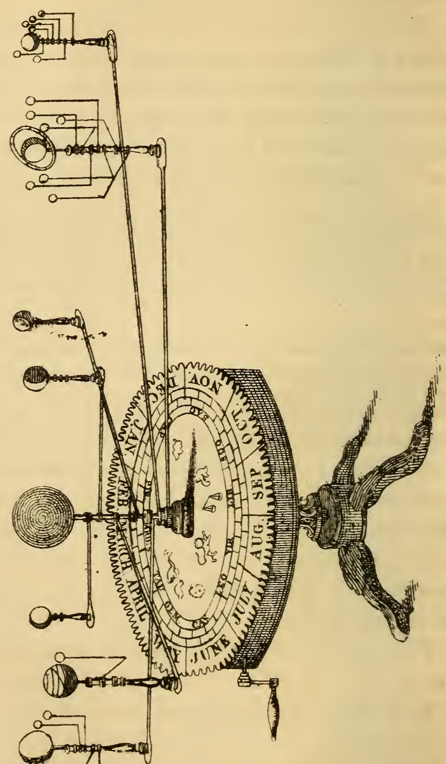
Thus, let A B (plate IX. fig. 3,) represent the plane of the ecliptic, and N C S the axis of the earth, Z C P will make an angle of 23½°, because the arc, Z P, contains 23½ parts of 360, the whole circle; and as A N contains the same number of degrees as Z P, its inclination must be 23½°.

The *Poles* are the extremities of the earth's axis, (plate IX, fig. 3;) N the north pole, S the south pole, P the north pole star, to which, and to the opposite part of the heavens, the axis always points. These extremities in the heavens appear motionless, while all the other parts seem in a continual state of revolution. The circle of motion in the heavenly bodies seems to increase with the distance from the poles.

The *Tropics* are two small circles parallel to the equator, at 23½ degrees distance from it; that to the north is called the tropic of Cancer, and that to the south the tropic of Capricorn.

The *Polar circles* circumscribe the poles of the world, at the distance of 23½ degrees. That on the north is called the Arctic, and that on the south the Antarctic circle.

The *distance* of these polar circles from the poles being fixed at 23½° (the same as the tropics from the equator) is because it is the *line of boundary between light and darkness,* when the sun is on either of the tropics, and throws his beams over and beyond the pole.



PLANETARIUM

The *Meridians* are so called because, as the earth revolves on his axis, when any one of them is opposite to the sun it is mid-day or noon along that line. Twenty-four of these lines are usually drawn on the globes, to correspond with the twenty-four hours of the day. Not that these are the only ones that can be imagined, for every place that lies ever so little east or west of another place has a different meridian.

Suppose the upper 12 (plate IX. fig. 3.) to be opposite the sun, it will of course be *noon* along that line, and the next meridian marked 1, being 15° east, will have passed the meridian 1 hour, consequently it will there be one in the afternoon, and so on, according to the order of the figures, to the lower 12, which being the part of the earth turned directly from the sun, it will be midnight on that meridian: as you proceed round, the next meridian will be one in the morning, the next two and so on, till you arrive at the upper 12, where you set off. Hence there must be a continual succession of day and night.

Note. This difference of time between places, lying under different meridians, is called longitude; or,

Longitude is an arc of the equator between the meridian of any place and the first meridian. In English geographers the first meridian passes through London or Greenwich, and the distance is reckoned east or west thence; *fifteen degrees* of longitude being equal to *one hour* of time.

To all places *eastward* of the first meridian, the time will be *before* London; if *west*, after London.

To reduce *longitude* to *time* divide by 15.

As the earth makes a complete revolution on its axis in 24 hours, it must pass over 360° in that time: and if you divide 360 by 24, the quotient, 15, will be the *number of degrees* passed over *in an hour*: hence 30° will be equal to *two* hours, 45° to three hours, &c.

Then if it be 12 o'clock at London, at Barbadoes, lying nearly 60° *west* of London, it will be 4 hours *earlier*, or 8 o'clock in the morning. At Petersburgh, 30° *east*, it will be 2 hours *later*, or 2 o'clock in th afternoon; and at Calcutta, almost 90° *east*, nearly 6 hours *later* in the afternoon.

To reduce *time* to *longitude*, multiply by 15.

A captain arriving at the Bermudas, finds the difference of time between them and London to be 4 hours and 20 minutes, which, multiplied by 15 (or by 3 and 5) will give 65°.

Latitude is the distance of any place from the equator, either north or south, or it is equal to the elevation of the pole above the horizon. The *latitude* of the *heavenly bodies* is reckoned from the ecliptic, and terminates in the arctic and antarctic circles, and their *longitude* begins at the point Aries.

The *Colures* are *two meridians*, which pass through the poles of the world; one of them through the points of Aries and Libra, and therefore called the *Equinoctial Colure;* the other through the solstitial points, Cancer and Capricorn, and therefore called the *Solstitial Colure.*

The *Zones* are five; namely, one torrid, two temperate, and two frigid.—The *torrid* is all that space between the tropics, and so called from its excessive heat; the *temperate* zones extend from the tropics to the polar circles; the *frigid* zones are comprised between the polar circles and the poles.

Solstitial points are the first points of Cancer and Capricorn; so called because the sun, when he is near either of them, seems to stand still, or to be at the same height in the heavens at noon for several days together.

Equinoctial points are the first points of Aries and Libra; so called, because when the sun is near either of them the days and nights are equal

As it is presumed that the pupil will have *previously* gone through a course of geography and the globes, the above *short definitions* may be sufficient, though they could not be omitted altogether.

CHAPTER XVII.

PLANETS' ORBITS ELLIPTICAL.

The orbits or paths described by the revolution of the planets round the sun, are not true circles, (as plate VIII. fig. 3,) but somewhat elliptical, that is, longer one way than another.

In a circle the periphery, or circumference, is equally distant from a point within, called its centre, A; but an ellipsis has two points called the *focuses*, or *foci*, as B C. In one of these, called its lower focus, is the sun. Hence, in every revolution of the planet it must be nearer the sun in one part of its orbit than it is at another.

Let S (plate VIII. fig. 5,) represent the sun, A B C D a planet in different parts of its orbit; when it is nearest the sun, as at A, it is said to be in its *perihelion;* when at B its *aphelion;* but when at C or D, its middle or *mean distance;* because the distance S C or S D is the middle between A S, the least, and B S the greatest; and half the distance between the two focuses is called the eccentricity of its orbits, as S E or E F.

ATTRACTION OF GRAVITATION.

By *attraction* is meant that property in bodies by which they have a tendency to approach each other.

Thus the magnet attracts the needle; this is called *attraction of magnetism:* and thus the feather suspended near the electrical conductor is attracted by it; this is termed *attraction of electricity.* And that property which connects or firmly unites the different particles of matter, of which the body is composed (as that of a stone,) is *attraction of cohesion.*

Attraction of Gravitation is a power by which bodies in general *tend toward each other;* and the attraction is in proportion to the quantity of matter which they contain; but the earth, being so immensely large in comparison of all other substances in its vicinity, destroys the effect of this attaction between smaller bodies by bringing them all to itself.

By attraction of gravitation, the sun, the largest body, *attracts* the earth and all the other planets, and they again *gravitate* or have a tendency to approach the sun The earth being larger than the moon, *attracts* her, and she gravitates towards the earth.

Upon this principle, a stone, when thrown from earth, is brought by the *earth's attraction* and its own *gravitating* power to the earth again.

The waters in the ocean, and indeed all the terrestrial bodies, gravitate towards the centre of the earth; and it is by this power that we stand on all parts of the earth, with our feet pointing to the centre. In short, it is by the attraction of gravity that a marble falls from the hand, a brick from the top of a building, or an apple from the tree. All bodies, by the power of gravity, have a tendency or disposition towards the earth.

One *law of attraction* is, "*That attraction decreases as the squares of the distances from that centre increase.*"

Any number multiplied into itself is a square number; thus, the square of 2 is 4, the square of 3 is 9 of 4 is 16, &c.

Suppose a planet at *P* (plate X. fig. 4,) to be twice as far from the sun as at A; then, as the square of the distance 2 is 4, the attraction at B will be four times less than at A, or, which is the same thing, A will be attracted with four times the force it would be at B.

Again, if the distance at A (fig. 5,) were four times less than at B, then, as the square of 4 is 16, the attraction at A would be sixteen times greater than at B.

The second law of gravity is, "*That bodies attract one another with forces proportional to the quantities of matter they contain.*" All bodies of equal magnitude contain not equal quantities of matter, for a ball of cork of equal bulk with one of lead, being more porous, does not contain so much matter.

So the sun, though a million of times as big as the earth, not being so compact and dense a body, contains a quantity of matter only 200,000 times as great, and hence attracts the earth with a force only 200,000 times more than the earth attracts him.

Hence suppose there are in a river two boats of equal bulk at any distance, suppose twenty yards, from each other, and that a man in one boat pulls a rope which is fastened to the other, the boats will meet in a point which is half way between them. If one boat were *three times* the bulk of the other, then the lighter would move *three times* as far as the heavier, or *fifteen* yards, while the heavier moved only *five*.

CHAPTER XVIII.

OF ATTRACTIVE AND PROJECTILE FORCES.

The sun, being so immense a body, would, by the power of attraction draw all the planets to him, if the attractive power were not counteracted by another force. It must therefore be observed that all *simple motion* is naturally *rectilineal*, that is, all bodies, if there were nothing to prevent them, would move in *straight lines*. But the planets' motions are *circular*, which is a *compound of two forces*, the one called the *attractive* or *centripetal force;* the other the *projectile* or *centrifugal force*.

Suppose a marble be shot from the hand along a smooth floor, if it meet with no impediment it will move *straight forward;* this is termed the *projectile force*, and its motion will be *rectilineal*. But if a ball be thrown into the air, unless projected perpendicularly, it will not continue to move in a straight line, but incline towards and fall to the earth; for the *resistance of the air*, and the *attraction of the earth* retard its progress: otherwise it would continue to move in a straight line, with a velocity equal to that which was at first impressed upon it.

The *joint action* of the attractive or projectile forces retains the planets in their orbits; the primaries round the sun, and the secondaries round their primaries.

When a stone is whirled round in a sling, its motion is *circular*. If the stone flies out, it will go off in a straight line.

This *straight line* is what is called the *tangent of a circle*, as A *a*, B *b*, &c. (Plate VIII. fig. 4;) for all bodies moving in a circle have a natural tendency to fly off in that direction. Thus a body at A will tend towards *a*, at B towards *b*, and so on, its *rectilineal* motion; but the central force (the action of the hand) acting against it, preserves its *circular* motion.

The moon and all the planets move by this law; and the attractive or centripetal force of the sun being equal to the projectile or centrifugal force of the planets, they are, by attraction, prevented from moving on in a straight line, and, as it were, drawn towards the sun; and by the projectile force from being overcome by attraction. They must therefore revolve in nearly circular orbits.

If, for instance, the projectile force were to cease acting upon the earth, it must fall to the sun: on the contrary, if the force of gravity were to cease upon the earth, it would fly off into infinite space.

The *secondary planets* are governed by the same laws in revolving round their respective primaries; for as by the attractive power of the sun, combined with the projectile force of the primary planets, they are retained in their orbits; so also the action of the primaries upon their respective secondaries, together with their projectile force, preserves them in their orbits.

If the attractive power of the sun were uniformly the same in every part of their orbits, they would be *true circles*, and the planets would pass over *equal portions* in *equal times;* but the attractive power of the sun is not uniformly the same; hence the orbits of the planets are not true circles, but a little *elliptical*, and they must pass over *unequal* parts of their orbits in *equal* portions of time.

By passing over *equal portions* in *equal times* may be understood passing from B to C, or from C to A, in the same time as from A to D, or from D to B.—(Plate VIII. fig. 5.)

By *unequal* portions in *equal* times, the centrifugal force would carry a planet from A to *a*, in the same time as it would from B to *b*. And in its orbit from A to *c*, as soon as from B to *d*.

A *double velocity* will balance a *quadruple* or fourfold *power* of gravity or attraction.—Hence, as the centri petal force is *four* times as great at A as at B, the centrifugal force is *twice* as great; and would describe the area or space contained between the letters A S *c*, in the same time as the area or space B S *d*. For according to the laws of the planetary motions, in their revolutions *they always describe equal areas in equal times.*

By *equal areas* is meant, that if the earth moves from A to *c* in the same time as from B to *d*, then the area of A S *c* will be equal to the area of B S *d*.

The orbits of the comets being very elliptical, the irregularity of their motions must be exceedingly great When *near* the sun, or in their *perihelion*, the *centripetal force* must act powerfully on the comet, and that force must be equalled by the *projectile force*, hence they will then move with amazing celerity; but when arrived at their *aphelion*, where the influence of the sun is weak, their motion is exceedingly slow, and the sun must appear little more than a fixed star.

If a body at rest receives two impulses at the same time, from forces in different directions, it will be made to move in a line that lies between the direction of the forces impressed. If on the ball A (Plate IX. fig. 1,) a force be impressed sufficient to make it move with a uniform velocity to the point B, in a second of time; and if another force be also impressed on the ball which would make it move to C, in the same time, the ball by means of the two forces acting together, will describe the line A *a* D.

In the beginning the Grand Mover impressed such a degree of motion upon these bodies as if not controlled, would have whirled them onwards in straight lines to endless lengths till they would have been lost to imagination in the abyss of space; but the *gravitating* power combined with the *projectile* determines their courses to an elliptical form, and obliges these bodies to perform their destined rounds

Fig 1.

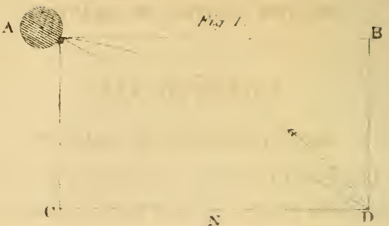


Fig. 2.

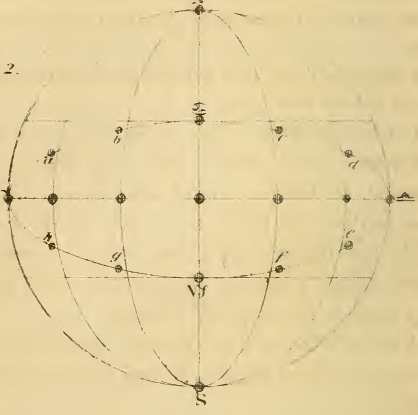
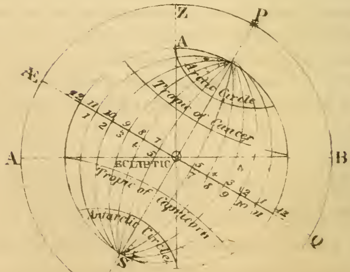


Fig 3.



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CHAPTER XIX.

ON THE CENTRE OF GRAVITY.

THE Centre of Gravity is that point of the body, in which its whole weight is, as it were, concentrated, and upon which, if the body be freely suspended, it will rest.

A weight of 1 cwt. at 10 feet from a prop, will balance another of 10 cwt. at 1 foot from it; or

Let two weights (Plate X. fig. 6) be nicely poised on a centre, round which they may freely turn: the heaviest, of 10 cwt., would move in a circle whose radius or distance from the centre would be *one* foot, while the lightest, of 1 cwt., would move in a circle whose radius would be 10 feet; *the centre round which they move is the centre of gravity.*

And thus the sun and planets move round an imaginary point as a centre, always preserving an equilibrium.

If the earth were the only attendant on the sun, as his quantity of matter is 200,000 times as great as that of the earth, he would revolve in a circle a 200,000th part of the earth's distance from him, in the same time as the earth is making one revolution in its orbit, or one year; but as the planets in their orbits must vary in their positions, the centre of gravity cannot be always at the same distance from the sun.

The quantity of matter in the sun so far exceeds that of all the planets together, that even if they were all on one side of him, he would never be more than his own diameter distant from his centre of gravity; therefore the sun is considered as the *centre* of the system.

As the *secondary planets* are governed by the same laws as their primaries, they, also, with their primaries, move round a centre of gravity.

Every system in the universe is supposed to revolve in like manner, and all these together to move round one *common centre.*

THE HORIZON.

The Horizon is that distant boundary of our sight where the heavens and the earth seem to meet all around us.

There are *two* horizons, termed the *rational* and the *sensible.* The *rational horizon* applies to the rising, setting, &c. of the sun, moon and stars. This horizon is supposed to encompass the globe exactly in the middle, or to be in a line with its centre H O, and to divide the heavens into two equal parts, being 90° distant from a point Z, over our heads, called the *zenith*, and the opposite point N, in the heavens directly under our feet called the *nadir.* (See Plate IV. fig. 2.)

The rational horizon is represented on the artificial globes by the broad paper circle or wooden horizon.

The *sensible horizon* respects land and water, and terrestrial objects. The extent of this horizon is greater or less, according as the spectator is more or less elevated.

Let *a* B *c*, (Plate IV. fig. 2,) represent the sensible horizon, and B the place of the spectator. Then an eye placed at 5 feet above the surface of the sea, sees 2¾ miles each way; but if it be elevated twenty feet, that is four times the height, it will see 5½ miles, or twice the distance.

The difference of the two horizons is this: the *sensible* is seen from the *surface* of the earth; the *rational* is *supposed* to be viewed from its *centre.*

Though the heavenly bodies can be viewed by the spectator only from the *sensible* horizon (or surface of the earth) as at B, yet they are really seen to rise and set when they are on the *rational* horizon, H O. This is owing to their vast distances from the earth, which occasion the difference arising from the positions of the surface or the centre to vanish.

The semi-diameter of the earth is not 4,000 miles, but 4,000 miles, compared with 95,000,000, the distance of the sun from the earth, is so little, that the difference of time is not discernible, not to mention the greater distance of the fixed stars. Even the rising and setting of the moon respects the rational horizon, whose distance is but 240,000 miles which bears a proportion to 4,000, as 60 to 1.

CHAPTER XX.

DAY AND NIGHT.

The form of the earth, as has been already noticed, approaches nearly to that of a true globe or sphere; and the *cause of the succession of day and night*, is the *rotation of the earth upon its axis* once in twenty-four hours.

For the meaning of *globe*, or *sphere*, *axis*, &c. see Preliminary Definitions, chap. 1.

A common observer may imagine that the sun, moon, and starry firmament revolve daily about the earth, while the earth remains at rest but their apparent motions are accounted for much more rationally.

Suppose A B C D (plate IV. fig. 2) to be the earth revolving on its axis according to the order of the letters, that is, from A to B, from B to C, &c. If the sun be fixed in the heavens at Z, and a line, H O, be drawn through the centre of the earth E, it will represent the circle, which, when extended to the heavens, is called the *rational horizon.*

The sun always illuminates one hemisphere of the earth, while the other hemisphere remains in darkness.

Therefore if the sun be supposed at Z, it will illuminate by its rays all that part of the earth that is *above* the horizon H O. To the inhabitants at A, its western boundary, it will appear just *rising;* to those situated at B, it will be *noon;* and to those in the eastern part of the horizon C, it will be setting.

A spectator cannot from any spot behold more than a *semicircle* of the heavens at any one time. If placed at A, he will see the concave hemisphere Z O N; and on the boundary of his view will be N and Z; consequently the sun at Z will be just coming into sight, or rising.

Then by the rotation of the earth, he will in a few hours come to B, when to him it will be *noon;* and those who live at B will have descended to C.

In this situation they will behold the hemisphere N H Z, and the sun, Z, will to them be setting; consequently it will be night to them till they return to A, when the sun will again appear to rise.

Therefore, however a spectator may imagine that the sun and heavenly bodies *are moving around him* from east to west, this is only *apparent;* just as a person passing swiftly in a carriage, or sailing near the shore, sees the houses, trees, and other fixed objects *moving* the contrary way; but he knows that this is merely a deception, and that it is *himself only* that moves.

This daily motion of the earth round its axis accounts equally for the apparent motions of the whole starry firmament about the earth every twenty-four hours.

By this motion the inhabitants of London are carried at the rate of 810 miles an hour, and those upon the equator about 1040.

The only points in the heavens that keep their positions, are the *two celestial poles*, which are opposite to the poles of the earth.

The stars above our horizon are as numerous by day as by night; but they cannot be discerned, because the sun's rays are so powerful as to render those coming from the fixed stars invisible.

Though our year consists of 365 days, the earth makes 366 revolutions on its axis, whilst it is going once round the sun.

Though the earth makes a complete revolution daily on its axis, yet we are not at all sensible of its motion. If its motion were *irregular*, it would no doubt be perceptible; but as it meets with no obstruction, the motion must be so uniform as not to be perceived.

That the earth may have such a motion, and we not be in the least sensible of it, is evident; for even the motion of a ship on *smooth water* is not sensibly perceived by those on board.

CHAPTER XXI.

OF THE ATMOSPHERE.

The Atmosphere is a thin, transparent, and fluid body, surrounding this terraqueous globe, and covering it to a considerable height. It possesses permanent elasticity and gravity, and is most dense or heavy near the earth, but becomes gradually rarer or lighter, the higher we ascend; so much so that at the tops of some high mountains it is difficult to breathe.

The whole mass of the atmosphere contains a heterogeneous collection of particles, exhaled from all solid or fluid bodies on the surface of the earth.

It serves not only to suspend the clouds, furnish us with wind and rain, and answer the common purposes of breathing, but is also the cause of the morning and evening twilight, and of all the glory and brightness of the firmament.

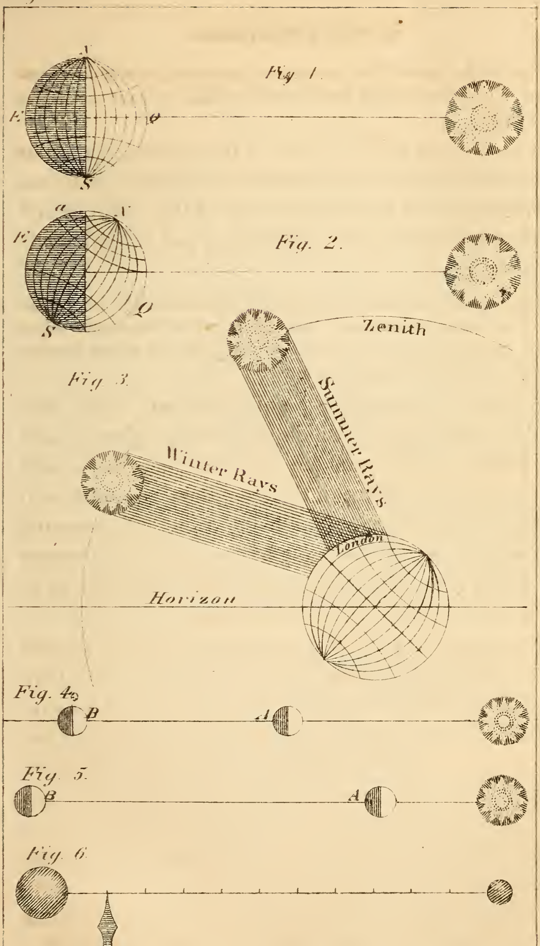
Experiments upon the air-pump prove, that without the air or atmosphere no animal could exist; without its aid all vegetation would cease. Sound could not be produced without it, nor would there be any rains or dews to moisten the ground.

Without an atmosphere, only that part of the sky would appear light in which the sun was placed; and if a person should turn his back, the heavens would appear dark as night, and the least stars would be seen to shine. But the atmosphere being strongly illuminated by the sun, reflects the light back upon us, and causes the whole heavens to shine with such splendour as to render the light of the stars invisible.

The height to which the atmosphere extends has not been exactly ascertained; but at a greater height than 45 miles it will not refract the rays of light from the sun.

The sun's rays falling upon the higher parts of it before rising, causes by reflection a faint light, which increases till he appears above the horizon; and in the evening decreases after he sets, till he is eighteen degrees below the horizon, where the morning twilight begins, and the evening twilight ends.

The beginning and end of twilight is also said to be when the least stars, viz those of the 6th magnitude begin to appear and disappear.



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CHAPTER XXII.

REFRACTION.

The rays of light, in passing out of one medium into another of a different density, deviate from a rectilineal course; and if the density of this latter medium continually increase, the rays of light, in passing through it, will deviate more and more from a right line towards a curve, in passing to the eye of an observer.

From this cause all the heavenly bodies, but the moon, except when in the zenith, *appear higher* than they really are. *This apparent elevation of the heavenly bodies above their true altitude, is caused by Refraction.*

Let A B C (plate XI. fig. 1.) represent the surrounding atmosphere *a* the *true* place of a star, *b* the apparent place. Let a ray fall from *a* on the surface of the atmosphere at A, and it will be refracted in the direction of the curve A D, because the density of the atmosphere increases as it approaches the earth's surface. Hence an observer at E will see the object at *b*.

It is in consequence of the refraction of the atmosphere, that *all heavenly bodies, except the moon, are seen for a short time before they rise* in the horizon, and also *after they have sunk below it.*

At some periods of the year the sun appears three minutes longer, morning and evening, than he would do were there no refraction; and about two minutes every day at a mean rate. Hence, when the sun is at T *below* the horizon, a ray of light T I, proceeding from him, comes straight to I, where falling on the atmosphere, it is turned out of its direct, or rectilineal course, and is so bent down to the eye of the observer at D, that the sun appears in the direction of the refracted ray above the horizon at S.

The effects of refraction may be seen thus: immerse a staff in a tub of water; if it be placed perpendicularly there will be no refraction; that is, it will not seem bent at all:—incline it a little towards the edge of the tub, and it will appear a little bent at the surface of the water; incline it still more, and the refraction will be greater.

Refraction is also shown in that well known experiment of putting any small object, as a shilling, &c., at the bottom of a basin or tub, then walking backward till the object is *just lost sight* of, and there standing while another person pours water into the basin, and the money will appear Now if the *edge* of the basin be called the *horizon*, the *water* the *atmosphere*, and the *shilling* the *moon*, it is clear that it will be seen *above* the horizon *when really below it.*

CHAPTER XXIII.

PARALLAX.

The *Parallax* of the sun and moon is the *difference between the altitude* of either object observed at the same instant of time by two spectators; one on the *surface* of the earth, and the other placed at the earth's *centre.*

The place of an object as observed from the earth's *surface* is called its *apparent place*; and as observed from the *centre*, its *true* place.

The parallax of the heavenly bodies is *greatest* when *in the horizon;* hence called the *horizontal parallax.*

The sun's mean parallax being only 8.6″, is seldom made use of in nautical calculations, except to determine the longitude, by means of observing the angular distance between the sun and moon.

The fixed stars, on account of their vast distance from the earth have no parallax.

As the parallax of the sun or moon or planets depresses, or causes them to appear *lower* than they really are, the difference must be added to their *apparent* altitudes, to obtain their *true* altitudes.

Let C (fig. 2, plate XI.) represent the centre of the earth; F D E, part of the moon's orbit; G *d e*, part of a planet's orbit; Z K, part of the starry heavens: now, to a spectator at A, upon the surface of the earth, let the moon appear at E, in the horizon of A, and it will be referred to K; but if viewed from the centre C, it will be referred to I: the difference between these places, or the arc I K, is called the *parallax in altitude;* and the angle A E C, is the *parallactic angle.*

The parallax will be *greater or less*, as the objects are more or less distant from the earth; thus the parallax I K, of E, is greater than the parallax *f* K, of *e*.

Also, with respect to any one object, when it is *in the horizon*, the parallax is the *greatest*, and *diminishes* as the body rises *to the zenith*, where the parallax is nothing. Thus, the horizontal parallax of E and *e*, is greater than that of D and *d;* but the objects F and G, as seen from either A or C, appear in the *same place* Z, or in the zenith.

CHAPTER XXIV.

EQUATION OF TIME.

Our summer half year is longer than the winter half year, by about eight days; occasioned by the inequality of the earth's annual motion. This inequality and the obliquity of the ecliptic are the causes of the difference of time between the sun and a well regulated clock. The clock keeps *equal* time while the sun is constantly varying, and shows only *apparent* time. The difference of these is called the *equation of time.*

Equal time is measured by a clock that is supposed to measure exactly 24 hours from noon to noon. And *apparent* time is measured by the apparent motion of the sun in the heavens, or by a good sun-dial.

This *difference* between *equal* and *apparent* time depends, *first*, upon the inclination of the earth's axis to the plane of its orbit; and *secondly*, upon the elliptic or oval form of the earth's orbit; for the earth's orbit being an ellipse, its motion (as has been already shown) is quicker in its *perihelion* than in its *aphelion.*

The rotation of the earth upon its axis is the most equable motion in nature, and is completed in 23 hours, 56 minutes, and 4 seconds. This space is called a *sidereal day*, because any meridian on the earth will revolve from a fixed star to that star again in this time.

Hence, if the earth had *only a diurnal motion*, the day would be nearly four minutes *shorter* than it is.

But a solar, or natural day, which our clocks are intended to measure, is the time which any meridian on the earth will take in revolving *from the sun to the sun again*, which is about 24 hours, sometimes a little more, sometimes less. This is occasioned by the earth's advancing nearly a degree in its orbit, in the same time that it turns eastward on its axis; and hence the earth must make *more than a complete* rotation before it can come into the same position with the sun, that it had the day before.

Some idea of this may be formed by the hands of a clock; suppose both of them to set off together at twelve o'clock, the minute hand must travel *more than a whole circle* before it will overtake the hour hand; that is, before they will be in the same relative position

Again, it must be observed that only four times a year the degrees on the ecliptic and the equation are equal; in other words, but four times a year is the sun's *longitude* and *right ascension* the *same in degrees;* and that is when he passes through the *equator and the tropics*, and then the sun and clocks go together, *as far as regards this cause;* but at other times they differ, because *equal* portions at the ecliptic pass over the meridian in unequal parts of time, on account of its obliquity.

To those who are acquainted with the globes this will appear evident by inspection. First, find the sun's longitude on the ecliptic, then his right ascension on the equator, and it will be seen that the *number of degrees* will be nowhere equal, except at the first point of Aries, Cancer, Libra and Capricorn. Or, it may be illustrated by the globe, thus: (plate IX. fig. 2:) Let ♈ and ♎ represent the equator · ♈, ♋, ♎ the northern half of the ecliptic, and ♈, ♑, ♎ the southern half. Make chalk or other marks, as at *a b c d e f g h*, all round the *equator* and *ecliptic* at equal distances (suppose at 20 or 30 degrees from each other,) beginning at Aries; now, by turning the globe on its axis, it will be seen that all the marks in the ecliptic, from Aries to Cancer, come *sooner* to the brazen meridian than their corresponding marks on the equator: those from the 1st of Cancer to Libra, come *later*;—those from Libra to Capricorn *sooner*, and those from Capricorn to Aries *later*

Note: Time, as measured by the *sun-dial* is represented by the marks on the *ecliptic;* that measured by a good *clock*, by those on the *equator.*

Hence it may be supposed, that while the sun is in the *first* and *third* quarters (plate IX. fig. 2,) that is. between ♈ and ♋, and ♎ and ♑, it will be *faster* than the clocks, and while in the other two quarters it will be *slower,* because equal portions of the ecliptic come *sooner* to the meridian in the 1st and 3d, and *later* in the 2d and 4th; but on account of the *elliptic form* o the earth's orbit, this will not be always exactly the case.

If the difference between time measured by the *dial* and clock, depend *solely* on the inclination of the earth's axis to the plane of its orbit, the clocks and dials ought to be together both at the *equinoxes* and the *solstices* (that is, on the 20th March, 21st June, 23d September, and 21st December;) but owing to the elliptic form of the earth's orbit, they coincide on other days not far distant.

An Ephemeris will show this: on the 20th March, and 23d of September, instead of the clocks and dials agreeing, there will be a variation of 6 or 8 minutes: and their times of coinciding will happen several days *later* in the *vernal*, and *earlier* in the *autumnal* equinox.

If the earth's motion in its orbit were uniform, which it would be if the orbit were circular, then the whole difference between *equal time* by the clock, and *apparent time* by the sun, would arise from the inclination of the earth's axis. But this is not the case; for the earth travels when *nearest* the sun, that is in the winter, *more than a degree* in 24 hours;—and when *farthest* from the sun, that is in summer, *less* than a degree in the same time.

From this cause the natural day would be of the greatest length when the earth was nearest the sun, for it must continue turning the longest time after an entire rotation, in order to bring the meridian of any place to the sun again; and the shortest day would be when the earth moves the slowest in her orbit.

The above inequalities, combined with those arising from the inclination of the earth's axis, make up that difference which is shown by the equation table in one of the outside columns of an Ephemeris.

CHAPTER XXV.

THE SEASONS.

THE *axis of the earth* is not upright or perpendicular to the plane of the ecliptic, but inclines to it 23½ degrees, as Z C P, making an angle with it of 66½ degrees, P C B, (plate IX. fig. 3.) The axis of the earth, in its annual orbit, always keeps parallel to itself.

See plate XII. fig. 2, where the earth is represented in four different parts of its orbit, still preserving its parallelism; see also plate XIII. fig. 1.

Although the earth's orbit is 190,000,000 of miles in diameter, yet the axis of the earth always points to the same part of the heavens; because compared with the distance of the fixed stars, 190,000,000 of miles is but a mere point.

As some illustration of this: suppose two *parallel lines* are drawn upon an elevation, three or four yards from each other. If we look along them they will *both* seem to point *directly* to the moon in the horizon, and perhaps three or four yards will bear as great a proportion to the moon's distance, as 190,000,000 of miles to the fixed stars.

What a striking proof of the inconceivable distance of the fixed stars, when, notwithstanding the earth in the course of the year continues to move from one part of its orbit to the other, yet the north pole appears at all times to point in exactly the same direction towards the polar star!

It is known that the earth has an annual course round the sun, because the sun, if seen to be in a line with a fixed star, any day or hour, will in a few weeks, by the motion of the earth, be found considerably to the east of such star, and he may be thus traced round the heavens to the same fixed star from which he set out.

These observations may be made in the day-time, because through the shaft of a very deep mine the stars are visible by day as well as by night. They are also rendered visible in the day by telescopes properly fitted up for the purpose.

The variety of the seasons depends upon the length of the days and nights, and upon the position of the earth with respect to the sun.

If the axis of the earth N S (plate X. fig. 1) were perpendicular to a line E Q, drawn through the centres of the sun and earth, there would happen equal day and night throughout the year; for as the sun always enlightens one half, every part must be half its time in the light, and the other half in darkness.

The two poles must be excepted, because to a person there situated, the sun would never appear to rise or set, but would always be moving round the horizon.

If the earth were thus situated, the rays would fall at all times vertically on the equator: and the heat excited by the sun being greater or less, in proportion as the rays fall more or less perpendicularly, the parts about the equator would be heated to a high degree, while the regions around the poles would be desolated by perpetual winter.

The *proportion* of heat materially depends on the degree of *perpendicularity* of the sun's rays. Let plate X. fig. 3, represent summer and winter rays in the latitude of London. It is evident that the summer rays strike more directly, and with greater force, as well as in greater numbers, on the same place.

The axis of the earth being inclined 23½° as in plate X. fig. 2, represents the position of the earth in our *summer season*, when all the parallel circles, except the equator, are divided into *two unequal parts;* and the length of their days and nights in each latitude will bear a proportion to the greater or less portion of their circumference in the enlightened and dark hemisphere.

If, for instance, *a b* represent that circle of latitude in which London is situated, it is evident that about *two-thirds* of it is in the light, and only one-third in darkness; hence, the sun will be two-thirds or 16 hours above the horizon, and 8 hours below it.

The parallel above *a b* is entirely in the light, and from thence to the pole there is continual day for some time; and *at* the pole the sun shines for six months together.

During that time the south pole is involved in darkness.

To those who live in equal latitudes, the one north, the other south, the length of the days to one will be always equal to the length of the nights to the other.

All parts of the globe enjoy the presence of the sun for the same length of time, in the course of the year.

CHAPTER XXVI.

THE SEASONS, CONTINUED.

The figure plate XII. fig. 2, represents the earth in four different parts of its orbit, or as situated with respect to the sun in the months of March, June, September, and December. The earth appearing nearer the sun in winter than in summer.

We are more than 3,000,000 of miles nearer to the sun in December than we are in June; and as the apparent diameter of any object *increases* in proportion as our distance from it is *diminished*, so the sun's *apparent* diameter is *greater* in our winter than in summer. In winter it is 32′ 36″, in summer but 31′ 31″.

It is ascertained that our summer (that is, the time that passes between the vernal and autumnal equinoxes) is nearly eight days longer than our winter, or the time between the autumnal and vernal equinoxes; consequently the motion of the earth is *slower* in summer than in winter, and therefore it must be a greater distance from the sun.

The *coldness* of our northern winters (though nearer to the sun,) compared with our summers, arises from the rays falling upon us so very *obliquely*, as was before noticed; and also from the *length* of the summer days and shortness of the nights; for the earth and air become heated by day, more than they can cool by night.

Both the hottest and coldest seasons of the year are not in the longest and shortest days, but a month after those times; for a body once heated does not grow cold instantaneously, but gradually, and *vice versa*. And as long as more heat comes from the sun in the day than is lost in the night, the heat will increase.

In June the *north* pole of the earth inclines to the sun (plate XII. fig. 2,) and consequently brings all the *northern* parts of the globe into the light; then *to the people of those parts it is summer*. But in December, when the earth is in the opposite part of its orbit, the north pole declines from the sun, and the *south* pole comes into light. It is then *winter to us*, and *summer to the inhabitants of the southern hemisphere*.

In March and September the axis of the earth neither inclines *to*, nor declines *from* the sun (plate XII. fig. 2,) but is perpendicular to a line drawn from its centre.

It is then *equal day and equal night at all places*, except at the poles, which are in the boundary of light and darkness, and the sun being directly vertical to, or over the equator, makes equal day and night at all places.

In March the real place of the earth is Libra, consequently the *sun will appear in the opposite sign, in Aries*, and be vertical to the equator

As the earth proceeds from March to June, its northern hemisphere comes into light, and on the 21st of that month, the sun is vertical to the tropic of Cancer.

In September the sun is again vertical to the equator, and of course the days and nights are again equal.

Following the earth in its journey to December, or when it has arrived at Cancer; the sun appears in Capricorn, and is vertical to the tropic of Capricorn. Now the southern pole is enlightened, and all the circles on that hemisphere have their *larger parts* in light. Of course it is summer to the southern, and winter to the northern hemisphere.

For the *increase and decrease of days and nights* we are indebted to the inclination of the earth's axis, and its preserving its parallelism. Hence from the 20th of March to the 21st of June the sun is vertical successively to all places between the equator and the tropic of Cancer, and consequently the days must *gradually lengthen.* From June to September the sun is again successively vertical to the same parts of the earth, but in a reverse order.

From September to December the sun is sucessively vertical to all places between the equator and the tropic of Capricorn, which causes the days to lengthen in the southern hemisphere.

CHAPTER XXVII.

THE MOON'S MONTHS, PHASES, ETC.

The time which the moon takes in performing her journey round the earth, is called *a month*, of which there are two kinds; a *periodical* month of 27 days, 7 hours, 43 minutes, and a *synodical* month of 29 days. 12 hours, 44 minutes, nearly.

This difference arises from the earth's annual motion in its orbit.

Suppose (plate XII. fig. 1.) S the sun; T the earth, in a part of its orbit Q T L. Let E be the position of the moon. If the earth had no motion, the moon would move round its orbit, E F G, &c. into the position of E again in 27 days, 7 hours, 43 minutes; but while the moon is describing her journey, the earth is passing through nearly a twelfth part of its orbit. This the moon must also describe, before the two bodies can come again into the same position that they before held with respect to the sun; and this takes up so much more time as to make her synodical month equal to 29 days, 12 hours, and 44 minutes. This is the cause of the division of time into months.

N. B. The moon's orbit is elliptical.

THE PHASES OF THE MOON.

The sun always enlightens one half of the moon, and though sometimes its whole enlightened hemisphere is seen by us, yet sometimes only a part, and at other times none at all, is discernible, according to her different positions in the orbit, with respect to the earth.

Suppose (plate XII. fig. 1,) A B C D E, &c. to represent the moon in different parts of her orbit round the earth, in which one half is constantly seen to be enlightened, as would appear if seen from the sun; then will the *enlightened parts* of the *outside figures* represent the appearance of the moon as seen from the earth.

When the moon is at E, *no part* of its enlightened side *is visible to the earth*. It is then *new* moon or *change*. And the moon being *in a line between* the sun and the earth, they are said to be in *conjunction*.

The outside figure opposite E is wholly *dark*, to show that the moon is invisible at *change*.

The whole illuminated hemisphere at A is turned to the earth, and this is called *full moon*, and the earth being *between* the sun and moon, they are said to be in *opposition*.

REFRACTION

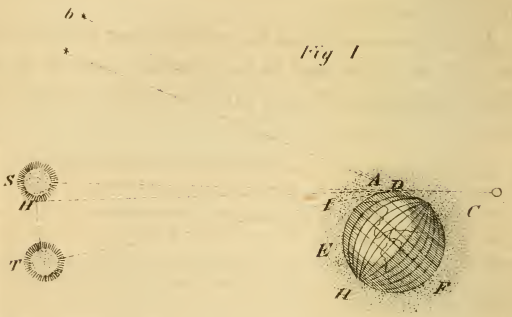


Fig. 1.

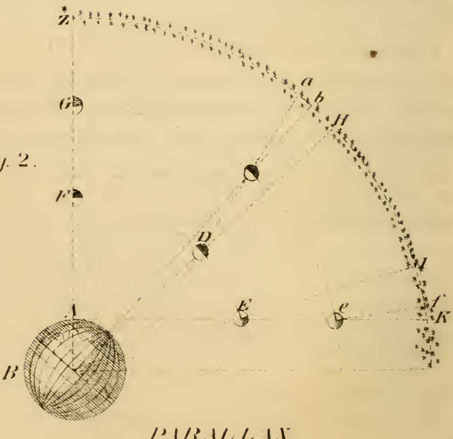


Fig. 2.

PARALLAX

When at F, a small part only will be seen from the earth, and that will appear *horned;* at G, one-half of the enlightened hemisphere is visible; it is then said to be in *quadrature.*

At H, three-fourths of the enlightened part are visible, and it is then said to be *gibbous;* and at A, the whole enlightened face is said to be *full*, and so of the rest.

The *horns of the moon* just after *change*, or conjunction, are turned to the *east;* after *full moon*, or opposition, they are turned to the *west.*

The various phases of the moon are often represented by a small globe or ivory ball suspended by a string. Let your *eye* represent the *earth*, and the *candle* the *sun;* then moving it round you, the full and the change will appear, and the different degrees of illumination in her orbit as seen from the earth. This will also illustrate the manner in which the moon, by keeping the same face always towards the earth, makes one complete revolution on her axis while she makes one in her orbit.

The moon's *apparent* motion is that of rising in the east and setting in the west, but this is owing to the revolution of the earth upon its axis. The moon's *real motion* round the earth is *from west by south to east.*

Her *real motion* may be known by remarking, when she is near any particular star, she will approach it from west to east, then be in conjunction with it, and then pass eastward of it.

CHAPTER XXVIII.

ECLIPSES.

The term Eclipse implies a privation of light, and in Astronomy the obscuration of the luminaries of heaven. Eclipses are either of the sun or moon.

ECLIPSE OF THE MOON.

An Eclipse of the Moon is occasioned by the interposition of the earth between the sun and moon, and consequently it must happen when the moon is in *opposition* to the sun, that is, at the *full* moon, as plate XIV. fig. 1.

If the plane of the moon's orbit coincided with the plane of the ecliptic, there would be an eclipse at every opposition and conjunction; but as that is not the case, there can be no eclipse at opposition or conjunction, unless at that time the moon be at or near the node.

The orbit of the moon does not coincide; for one-half is elevated more than 5 degrees and one-third *above* that of the earth; and the other half is as much *below* it. Hence she mostly passes either above or below the shadow of the earth.

The greatest distance from the node at which an eclipse of the moon can happen is 12 degrees. When she is within that distance, there will be a *partial* or *total* eclipse, according as a part or the whole disc or face of the moon falls within the earth's shadow. If the eclipse happen exactly when the moon is *full in the node*, it is called a *central* or *total eclipse*.

The duration of the eclipse lasts all the time the moon is passing through the earth's shadow; and the shadow being considerably wider than the moon's diameter, an eclipse of the moon sometimes lasts three or four hours.

The shadow is also of a conical shape, and as the moon's orbit is an ellipse, and not a circle, the moon will at different times be eclipsed when she is at different distances from the earth.

and accordingly as the moon is farther from, or nearer to the earth the eclipse will be of a greater or less duration; on account of the slower motion of the moon, when more distant from the earth.

An eclipse of the moon always *begins* on the moon's *left* side, and goes off on her *right* side.

This may be conceived by pre-supposing that the earth casts shadow far beyond the moon's orbit; and as the moon's course is from west to east, her *eastern* edge must necessarily first enter that shadow.

By knowing exactly at what distance the moon is from the earth, and of course the width of the earth's shadow at that distance, it is that all eclipses are calculated with accuracy for many years before they happen.

It is found also, that in all eclipses the shadow of the earth is conical, which is a demonstration that the body which casts it is of a spherical form, for no other sort of figure would, in all positions, cast a conical shadow. This is mentioned as another proof that the earth is a spherical body. The *conical form* of the shadow proves also that the *sun* must be a *larger body* than the earth; for if two bodies were *equal* to one another (as plate XIV. fig. 3,) the shadow would be *cylindrical;* and if the earth were the *larger* body (as fig. 14,) its shadow would be of the figure of a *cone* which had lost its vertex.

ECLIPSE OF THE SUN.

An Eclipse of the Sun happens when the moon, passing between the sun and the earth (plate XIV. fig. 2, intercepts the sun's light from coming to the earth, which can happen only at the change, or, when the moon is in conjunction.

This may be illustrated by suspending a small globe, or ivory ball, in a right line between the eye and the candle.

The ball intercepting the light of the candle, represents an eclipse of the sun; for as light passes in a right line, the sun is hidden from that part of the earth which is under the moon, and therefore he must be eclipsed.

If the whole of the sun be obscured by the body of the moon, the eclipse is *total:* if only a *part* be darkened, it is a *partial* eclipse ; and so many twelfth parts of the sun's diameter as the moon covers, so many digits are said to be eclipsed.

The word *digit* means a twelfth part of the diameter of either the sun or the moon.

It is only when the moon is *in* perigee and very near one of the nodes, that she can cover the whole disc of the sun, and produce a total eclipse ; and no eclipse of the sun can happen but when she is within 17 degrees of either of her nodes. At all other *new* moons she passes either above or below the sun, as seen from the earth ; and at all other full moons above or below the earth's shadow.

An eclipse of the moon, if central, must be total ; but an eclipse of the sun may be central and *not total.* Hence there are what are termed *annular* eclipses, when a ring of light appears round the edge of the moon during an eclipse of the sun. It has its name from the Latin word annulus, "a ring." This kind of eclipse is occasioned by the moon being at her greatest distance from the earth at the time of an eclipse ; because in that situation, those who are under the point of the dark shadow will see the edge of the sun, like a fine luminous ring, all around the dark body of the moon.

It is only when the moon is *nearest* the earth at an eclipse of the sun, that the eclipse can be total : a total eclipse is, therefore, a very curious and uncommon spectacle. Total darkness cannot last more than six or seven minutes.

There *must* be two solar eclipses in a year, and there may be *but two.* But there may *not be one lunar eclipse* in the course of a year. When, therefore, there are only two, they are both of the sun.

There *may* be three *lunar* eclipses, and there can be no more. There may also be seven eclipses in a year; but in this case, *five* will be of the sun, and *two* of the moon. But as there are seven eclipses in the year but seldom, the mean number will be about four.

The ecliptic limits of the sun are greater than those of the moon, and hence there will be more solar than lunar eclipses, nearly as three to two. But more lunar than solar eclipses are seen at any given place, because a lunar eclipse is visible to a whole hemisphere at once: whereas a solar eclipse is visible only to a part; and therefore there is a greater probability of seeing a lunar than a solar eclipse.

CHAPTER XXIX.

POLAR DAY AND NIGHT, ETC.

There being *sometimes no night*, at *other times no day*, for a while, *within the polar circles*, is thus accounted for. The sun being always vertical to some one point, and only one at the same time on the globe, and shining ninety degrees from that point each way, only one complete hemisphere can be at one time illuminated. Therefore, when on the equator, his rays must extend to each pole. When he has advanced one, two, or ten degrees *above* the equator, the rays must extend the *same number* of degrees *beyond* the north pole, and consequently be withdrawn as many from the south pole. And when vertical to the tropic of Cancer ($23\frac{1}{2}$ degrees north of the equator) he must shine the same number of degrees on the other side of the pole, that is, to the polar, or arctic circle.

While he thus shines there can be *no night* within that *north polar circle*, and of course *no day* within the *southern polar circle ;* for the sun's rays, reaching but 90 degrees every way, will then extend but to the antarctic circle.

For the reasons above given, it is evident that there can be but *one day* and *one night* at the poles, *each half a year* in length. For, from the moment the sun ascends north of the equator, ***his rays reach over the pole***, which he continues to illuminate till he returns to the equator, a period of half a year. During this time there can be no night at the north pole, nor any day at the south pole.

The reverse of all this, while the sun is *south of the equator*, may be equally applied to the south pole. The inhabitants of the polar regions, however, even when the sun is absent, are *not in total darkness ;* for twilight continues to enlighten them till the sun is 18 degrees below their horizon ; and his greatest depression is but $5\frac{1}{2}$ degrees more, ($23\frac{1}{2}$ degrees,) equal to the inclination of the earth's axis.

Besides this, the moon is *above* the horizon of the poles a *fortnight together ;* for as she passes through the whole ecliptic *monthly*, which lies one half north, and the other half south of the equator, she must continue to shine over one or other of the poles till she returns to the equator again.

A *third* benefit they receive to mitigate their darkness is, that as the moon *when at the full* is ever in the *opposite sign* to the sun, their winter full moons must have the ***highest altitude***, describing nearly the same track as their summer sun.

Note.—We say *nearly the same track*, because the moon mostly *varies a little* (sometimes above 5°) from the sun's course in the ecliptic.

When the sun is in the equator, he *rises exactly* *east*, and *sets exactly west;* but during the summer half year he rises to the *north* of the east point, and sets as much north of the west; that is, if he rises 10° north of the east, he sets 10° north of the west point &c., the place of his rising varying with his declination During the opposite half year he rises *south* of the east, and sets south of the west.

It must be observed, that though we say the sun sets as many de grees N. of the W. as it rises N. of the E., &c. yet there will be a *small variation* from sun-rising to sun-setting, as the earth is advancing in its orbit.

This, to some, will be more clearly explained on the globe. If the sun were to remain stationary in the ecliptic, from his rising to his setting there would be *no variation.* But the sun advances in the ecliptic nearly *a degree* in 24 hours, which, if correctly allowed for in working the problem, will show a small variation between the rising and the setting point. Hence, from the shortest to the longest day the sun *sets* rather more towards the *north* than he rises; but from the longest to the shortest day the variation is more *southerly.*

CHAPTER XXX.

UMBRA AND PENUMBRA, IN ECLIPSES.

The *Umbra* and *Penumbra* in an eclipse may be thus explained: (Plate XIV. fig. 5.) Let S be the sun, M the Moon, A B or C D, the surface of the earth; then *x* V *z*, will be the moon's *umbra*, in which no part of the sun can be seen. The space comprehended between the umbra and *x o k* and *z* P *g*, is called the *penumbra*, in which part of the sun only is seen.

Now it is evident that if A B be the surface of the earth, the space between *m n*, where the umbra falls, will suffer a *total eclipse;* the parts *o m* and *n* P, will have a *partial eclipse;* but to all the other parts of the earth there will be *no eclipse.*

But as the earth is at different times at different distances from the moon, suppose, again, C D to be the surface of the earth; then as the umbra reaches but to V, the space within *c f* will suffer an *annular eclipse*, and the sun will appear all round about the moon in the *form of a ring.* The parts *k c* and *f g* will have a *partial eclipse*, and to the other parts of the earth there will be *no eclipse.* Hence it is evident that in this last case, supposing C D the earth, there can be *no total eclipse anywhere*, as the moon's umbra does not reach the earth.

According to M. du Sejour, an eclipse can never be annular longer than 12 minutes 24 seconds, nor total longer than 7 minutes 58 seconds.

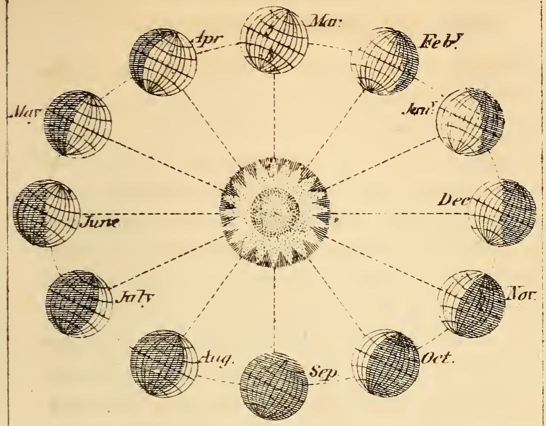
The moon's mean motion about the centre of the earth is at the rate of about 33′ in an hour; but 33′ of the moon's orbit is about 2,280 miles, which therefore may be considered as the velocity with which the moon's shadow passes over the earth; but this is the velocity upon the *surface* of the earth, only, where the shadow falls perpendicularly upon it. In every other place the *velocity of the surface will be increased.*

But again, the earth having a rotation about its axis, the *relative velocity* of the moon's shadow over any point of the surface will be even *different* from this. For if the point be moving in the direction of the shadow, the velocity of the shadow on that point will be diminished and consequently the time in which the shadow passes over it will be increased; but if the point be moving in a contrary direction to that of the shadow (as is the case when the shadow falls on the other side of the pole) the time will be diminished.

From the above it is evident that *the length of a solar eclipse at any place is affected by the earth's rotation about its axis.*

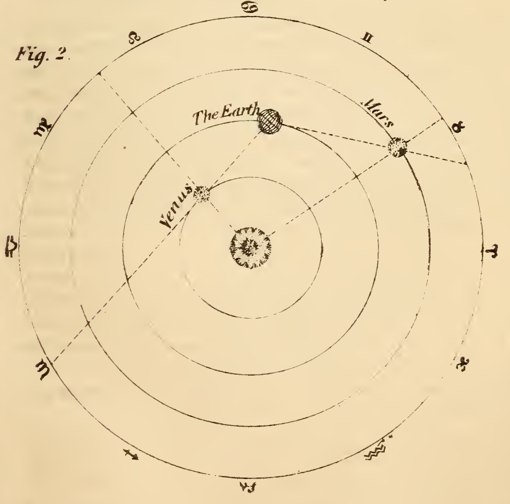
The different eclipses of the sun may be thus explained: let each of the three *lower* circles (plate XV. fig. 3.) represent the earth, and O R its orbit. Let each of the three *upper* circles represent the moon's

Parallelism of the Earth's Axis



Heliocentric and Geocentric Longitude

Fig. 2.



penumbra, P U the line described by the centres of the moon's umbra and penumbra at the earth; N the moon's node; E the earth's centre; *p n* the moon's penumbra; *u* the umbra. Then in the first position, the penumbra *p n* just passes by the earth, without falling upon it, and therefore there will be no eclipse. In the second position, the penumbra *p n* falls upon the earth, but the umbra *u* does not. In the third position, both the penumbra *p n* and the umbra *u* fall upon the earth; therefore, where the penumbra falls there will be a *partial* eclipse, and where the umbra falls there will be a *total* eclipse; and to the other parts of the earth there will be *no eclipse.*

As a description of a total eclipse of the sun may be interesting to the young reader, we select a few particulars of that which happened April 22d, 1715. Captain Stannyan, of Berne, in Switzerland, says, "the sun was totally dark for four minutes and a half; that a fixed star, and planet, appeared very bright;" J. C. Facis, of Geneva, says, "there was seen, during the whole time of the total immersion, a whiteness, which seemed to break out from behind the moon. Venus, Saturn, and Mercury were seen by many. Some persons in the country saw more than sixteen stars, and many people on the mountains saw the sky starry as on the night of a full moon. The duration of the total darkness was about three minutes."

Dr. J. J Scheuchzer, at Zurich, says, "that both planets and fixed stars were seen; the birds went to roost; the bats came out of their holes, the dew fell on the grass, and a manifest sense of cold was experienced. The total darkness lasted at Zurich about four minutes."

Dr. Halley, who observed this eclipse in London, says, "that about two minutes before the total immersion, the remaining part of the sun was reduced to a very fine horn; and for the space of about a quarter of a minute, a small piece of the southern horn seemed to be cut off from the rest, and appeared like an oblong star. This appearance could proceed from no other cause but the inequalities and elevated parts of the moon's surface, by which interposition, part of that exceedingly fine filament of light was intercepted.

"A few seconds before the sun was totally hid, there discovered itself round the moon a luminous ring, in breadth about a digit, or perhaps a tenth part of the moon's diameter; it was of a pale whiteness, or rather pearl colour, seeming to me a little tinged with the colours of the *iris*, whence I concluded it was the moon's atmosphere; for it in all respects resembled the appearance of an enlightened atmosphere viewed from afar, but whether it belonged to the sun or the moon, I shall not take upon me to decide.

"As to the degree of darkness, it was such that one might have expected to see more stars than were seen in London. The planets, Jupiter, Mercury, and Venus, were all that were seen by some; Capella and Aldebaran were also seen. Nor was the light of the ring round the moon capable of effacing the lustre of the stars, for it was vastly inferior to that of the full moon, and so weak that I did not observe it cast a shade. I forbear to mention the chill and damp with which the darkness of this eclipse was attended; or the concern that appeared in all sorts of animals, birds, beasts, and fishes, upon the extinction of the sun, since ourselves could not behold it without emotion"

CHAPTER XXXI.

THE TRANSIT OF VENUS.

The following illustration of the *transit of Venus*, which is an object of great interest and utility, will now be understood:

Let S (plate XIV. fig. 6.) represent the sun, and V V′ Venus at the beginning and end of her transit, as she would appear from the earth's *centre;* also let E E′ be the corresponding positions of the earth at those times.

Then, if the observer would be situated at C, the centre of the earth, when Venus entered on the solar disc, she would appear as a small black spot at *s*, and the true place of both her and the eastern limb of the sun would be *s*. But if the observer were situated at any point on the earth's surface, as P, the apparent place of Venus would be at v, and the apparent place of the corresponding limb of the sun would be at P; and consequently Venus would appear to the eastward of the sun, by a space equal to the arc v p, which is the difference of the parallaxes of these two bodies.

Hence the immersion of Venus would not take place so soon to an observer at P as to one at C, by the time she would require to describe the apparent arc v P.

Now, as the transit always must take place at the *inferior* conjunction of the planet, the motions of both Venus and the earth will then be from east to west, while the motion of the earth on its axis is in a contrary direction.

Consequently, while Venus and the earth move in their orbits from V to V′, and from E to E′, the point P, which at the commencement of the motion was *west* of the centre, will at the end of it be on the *east* of it, as at P′. Hence the observer, who was supposed to be situated at C, would perceive Venus just leaving the sun's disc, and her apparent place would be *s′;* while to the observer at P′, her apparent place would be at v'. and that of the sun's western limb at P. The apparent distance of Venus from the sun at the end of the transit is therefore the arc v' P, which is equal to the difference of the parallaxes of the sun and Venus, as before.

Consequently the *time of the duration*, as observed at the point P, will be *less* than the absolute duration, by the time which the planet would require to describe the two apparent arcs v P and v' P, or *twice the difference* of the parallaxes of the sun and the planet.

The principal use to which astronomers apply the transits of Venus is in determining the distance of t e sun from the earth by means of his parallax, which, on account of its smallness, they have in vain attempted to ascertain by various other methods.

These transits are also applied with great effect in ascertaining the longitude of places; in correcting the elements of the planets, especi ally the places of the *aphelia*, the situation of the nodes, and the incli nations of the orbits.

The transits of Mercury take place much oftener than those of Venus, but on account of his greater distance from the earth, and the small ness of his parallax from the sun, they are not susceptible of equa. utility with those of Venus, except for the determination of terrestial longitude, for which they are superior.

OCCULTATION OF THE FIXED STARS.

Nearly related to eclipses of the sun, is the *occultation of the fixed stars*, which implies the obscuration of these heavenly bodies by the moon or a planet.

The only method of ascertaining whether an occultation will happen, is that of calculating the place of the moon at the ecliptic conjunction. The course of the moon, however, affords limits to these occurrences, which enable astronomers to judge when they will take place; for *Cassini* has remarked that all stars whose latitudes do not exceed 6° 36′ either north or south, may suffer an occultation on *some part* of the earth; and if the latitudes are not more than 4° 32′, the occultation may happen on *any part* of the earth.

By *conjunction* is meant having the same *longitude;* or answering to the same degree of the ecliptic.

By *latitude* of a star (as has been shown in page 49) is meant its *distance* from the *ecliptic*, either north or south.

To determine when these eclipses or occultations will happen, we must compute the time of the con·junction, and the true latitude of the moon at that epoch,

Fig. 1

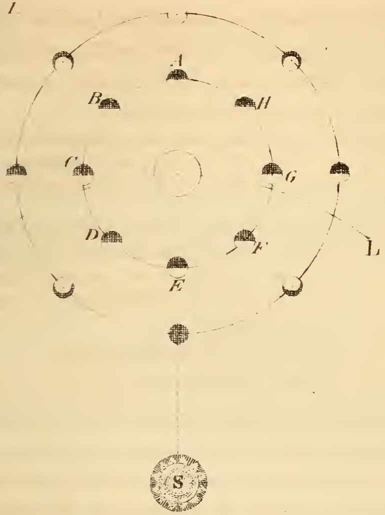
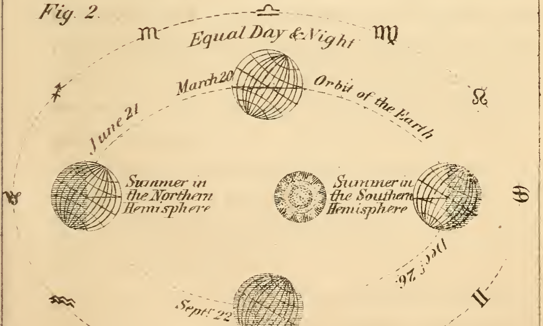

A
B
H
C
G
D
F
E
Q
L
S

Fig. 2.


Equal Day & Night
March 20
Orbit of the Earth
June 21
Summer in the Northern Hemisphere
Summer in the Southern Hemisphere
Dec. 21
Sept. 22
Equal Day and Night
Signs of the Zodiac

[illegible]

and then, if the difference of the latitudes of the moon and the star exceed 1° 20′, there cannot be any occultation; but if this difference be less than 51′, there must be an eclipse of the star on some part of the earth: between these limits the occultation may or may not take place.

In very different places of the earth, a great difference will result from the change in the moon's parallax, and this difference may be even so great as altogether to prevent the obscuration from taking place.

CHAPTER XXXII.

THE HARVEST MOON.

Owing to the daily progress the Moon is making in her orbit from west to east, she rises about 50 minutes later every day, when near the equator, than on the day preceding. But in places of considerable latitude there is a remarkable difference, especially about the time of *harvest*, when at the season of full moon she rises to us for several nights together only from 17 to 25 minutes later on the one day than on that immediately preceding.

To those who live in the latitude of London, when the moon is in the 10th of Pisces, she rises 25 minutes later than on the day preceding; the 23d of Pisces, 20 minutes later; the 7th of Aries, 17 minutes later; the 20th, 17 minutes; the 3d of Taurus, 20 minutes; and the 16th, 24 minutes later.

To persons who live at considerable distances from the equator, the *autumnal full moon* rises very soon after sun-set for several nights together; and by thus succeeding the sun before the twilight is ended, the moon prolongs the light, to the great benefit of those that are engaged in gathering in the fruits of the earth Hence the full moon at this season is called the *Harvest Moon.*

It is believed that this was observed by persons engaged in agriculture at a much earlier period than that in which it was noticed by astronomers. The former ascribed it to the goodness of the Deity, not doubting but that he had so ordered it for their advantage.

About the equator, where there is no such variety of seasons, and where the weather changes but seldom, and at stated times, moonlight is not wanted for gathering the fruits of the earth, and there the moon rises throughout the year at nearly the equal intervals of 50 minutes, as before observed.

At the polar circles, the autumnal full moon rises at sun-set, from the first to the third quarter; and at the poles, where the sun is for half a year absent, the winter full moons shine constantly without setting, from the first to the third quarter.

The moon's path may be considered as nearly coinciding with the ecliptic; and all these phenomena are owing to the different angles made by the horizon and different parts of the moon's orbit, or in other words, by the moon's orbit lying sometimes more oblique to the horizon than at others. In the latitude of London as much of the ecliptic rises about *Pisces* and *Aries* in two hours as the moon goes through in six days; therefore while the moon is in these signs, she differs but two hours in rising for six days together, that is, one day with another, about 20 minutes later every day than on the preceding.

These parts or signs of the ecliptic which *rise* with the *smallest* angles, *set* with the *greatest*, and *vice versa*

And whenever this angle is least, a greater portion of the ecliptic rises in equal times than when the angle is larger. This may be seen by elevating the pole of the globe to any considerable latitude, and then turning it round on its axis.

Consequently when the moon is in those signs which rise or set with the smallest angles, she rises or sets with the least difference of time; and on the contrary, with the greatest difference in those signs which rise or set with the greatest angles.

Let plate XV. fig. 2, represent the globe, the north pole being elevated to about 51½°, with Cancer on the meridian, and Libra rising in the east. In this position the ecliptic has a high elevation, making an angle with the horizon of 62°.

But let the globe be turned half round on its axis till Capricorn comes to the meridian, and Aries rises in the east, then the ecliptic will have the low elevation, above the horizon (fig. 2,) making an angle of only 15° with it. This angle is 47° less than the former angle, equal to the distance between the tropics.

In *northern* latitudes, the *smallest* angle made by the ecliptic and horizon is when Aries rises, at which time Libra sets; the *greatest* when Libra rises, at which time Aries sets. The ecliptic rises fastest about Aries, and slowest about Libra. Though Pisces and Aries make an angle of only about 15° with the horizon *when they rise*, to those who live in the latitude of London they make an angle of 62° with it *when they set.* The Moon, quitting Pisces and Aries, arrives in about fourteen days at the opposite signs, Virgo and Libra, and then she differs almost four times as much in rising; being one hour and about fifteen minutes later every day or night than on the preceding.

Those who are acquainted with the globes will easily demonstrate this problem by putting small patches on the ecliptic, at distances from each other equal to the moon's daily course; which (deducting for the sun's advance) is little more than 12° Then (after rectifying the globe for the latitude, and setting the hour-index to 12,) by turning the globe round, and observing the time of the appearing and disappearing of the patches, the variation in the time of the moon's rising or setting will be shown on the hour circle.

As the moon can never be full but when she is opposite to the sun, and the sun is never in Virgo or Libra but in our autumnal months, September and October, it is evident that the moon is never full in the opposite signs, Pisces and Aries, but in those two months. Therefore we can have only *two full moons* in a year, which rise, for a week together, very near the time of sun-set. The former of these is called the *Harvest Moon*, and the latter the *Hunter's Moon.*

CHAPTER XXXIII.

THE HARVEST MOON, CONTINUED.

Though there are but two full moons in the year that rise with so little difference of time, yet the phenomenon of the moon's rising for a week together so nearly in point of time, occurs every month, in some part or other of her course.

In *Winter* the signs Pisces and Aries rise *about noon;* and the sun, in Capricorn, is then only a quarter of a circle distant. Therefore the moon, while passing through them, must be only in her *first quarter* Hence her rising is neither regarded nor perceived.

In *Spring*, these signs *rise with the sun*, because he is then in them, and as the moon changes while passing through the same sign with the sun, it must then be *the change*, and hence invisible.

In *Summer*, they rise about midnight, for the sun being three signs, or a quarter of a circle before them, the moon is in them, or about her *third* quarter. Hence rising so late, and giving but little light, her rising passes unobserved.

The moon goes round the ecliptic in 27 days, 8 hours but not from change to change in less than 29 days, 12 hours; so that she must be *once* in *every* sign, and *twice* in some one sign every lunation.

If the earth had no annual motion, every new moon would fall in the same sign and degree of the ecliptic; and every full moon in the opposite: for the moon would go exactly round the ecliptic from change to change. So that if she were once full in any sign, suppose in Pisces or Aries, she would always be full there.

But in the time the moon goes round the ecliptic from any conjunction or opposition, the earth goes 27½ degrees, that is, almost a sign forward; so that the moon must go 27½ degrees *more than round*, before she can be in conjunction with or opposite to the sun again. Hence, if she were in her conjunction at the first degree of Aries, she would, in one lunation, not only return to the same point, but repass it, and go twice over Aries to the 27½ degree.

To the inhabitants at the equator the north and south poles appear in the horizon; and therefore the ecliptic makes the same angle southward with the horizon when Aries rises, as it does northward when Libra rises; consequently she rises and sets not only at *nearly* equal angles with the horizon, but at the equal distance *in time* of about 50 minutes, all the year round: and hence there can be no particular harvest moon about the equator.

The farther any place is from the equator if it be not beyond the polar circles, the angle which the ecliptic and the horizon make gradually diminishes when Pisces and Aries rise.

This the globe itself will fully illustrate; for the more the north pole is elevated, the more nearly does the ecliptic coincide with the horizon; that is, the angle is diminished.

Though in northern latitudes the autumnal full moons are in Pisces and Aries; yet in southern latitudes it is just the reverse, because the seasons are the contrary: for Virgo and Libra rise at as small angles with the horizon in southern latitudes, as Pisces and Aries do in the northern: and therefore the harvest moons are just as regular on one side of the equator as on the other.

In this illustration of the harvest moon, we have supposed the moon to move *in* the ecliptic, from which the sun never deviates; but the orbit in which the moon really moves (as was noticed under the article Eclipses) is different from the ecliptic; one half being elevated 5½ degrees above it, and the other half as much depressed below it. And this oblique motion causes some small difference in the time of her rising and setting from what has been above mentioned.

At the polar circles, the full moon neither rises in summer, nor sets in winter. For the winter full moon being as high in the ecliptic as the summer sun, she must therefore continue, while passing through the northern signs, above the horizon; and the summer full moon being as low in the ecliptic as the winter sun, can no more rise, when passing through the southern signs, than he does.

CHAPTER XXXIV.

OF LEAP-YEAR.

The time our earth takes to make one complete revolution, in its orbit round the sun, we call a year. To complete this with great exactness is a work of considerable difficulty. It has mostly been divided into twelve months of 30 days.

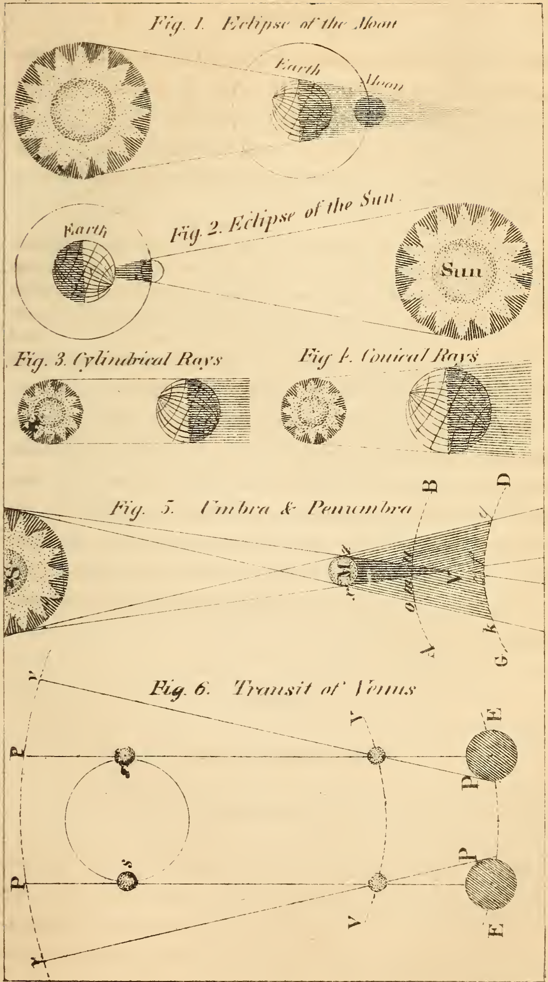


Fig. 1. Eclipse of the Moon
Earth
Moon
Fig. 2. Eclipse of the Sun.
Earth
Sun
Fig. 3. Cylindrical Rays
Fig 4. Conical Rays
Fig. 5. Umbra & Penumbra
B
D
S
M
V
A
G
Fig. 6. Transit of Venus
E
P
V
E
P
P
E
V
P

P S Duval

[illegible]

The ancient Hebrew months consisted of 30 days each, except the last, which contained 35. Thus the year contained 365 days. An intercalary month at the end of 120 years supplied the difference.

The Athenian months consisted of 30 and 29 days alternately, according to the regulation of Solon. This calculation produced a year of 354 days, and a little more than one-third. But as a solar month contains 30 days, 10 hours, 29 minutes, Meton, to reconcile the difference between the solar and lunar year, added several *embolismic*, or intercalary months, during a *cycle*, or revolution of 19 years.

The Roman months, in the time of Romulus, were only ten of 30 and 31 days. Numa Pompilius, sensible of the great deficiency of this computation, added two more months, and made a year of 355 days.

The Egyptians had fixed the length of their year to 365 days.

Julius Cæsar, who was well acquainted with the learning of the Egyptians, was the first who attained to any accuracy on the subject. Finding the year established by Numa ten days shorter than the solar year, he supplied the difference, fixed the length of the year to be 365 days, 6 hours, and regulated the months according to the present measure. To allow for the six odd hours, he added an intercalary day every fourth year to the month of February, reckoning the 24th of that month *twice*, which year must of course consist of 366 days, and is called *Leap-year*. From him it was denominated the Julian year.

This year is also called *Bissextile* in the Almanacs, and the day added is termed the intercalary day.

The Romans, as has been observed, inserted the intercalary day, by reckoning the 24th twice, and because the 24th of February in their calendar was called *sexta calendas Martii*, the sixth of the calends of March, the intercalary day was called *bis sexta calendas Martii*, the *second sixth* of the calends of March, and hence the year of intercalation had the appellation of *Bissextile*. We introduce in leap-year a new day in the same month, namely, the 29th.

To ascertain at any time what year is leap-year divide the date of the year by 4, if there is no remainder it is leap-year. Thus 1824 was leap-year. But 1825 divided by 4, leaves a remainder of 1, showing that it was the first year after leap-year; and as 1829, divided by 4, leaves 1, it will be the first after leap-year.

But the true solar year does not contain exactly 365 days, 6 hours, but 365 days, 5 hours, 48 minutes, and 49 seconds; which to calculate for correctly, requires an additional mode of proceeding: 365 days, 6 hours, exceeds the true time by 11 minutes, 11 seconds, every year, amounting to a whole day in a little less than 130 years.

Notwithstanding this, the Julian year continued in general use till the year 1582, when Pope Gregory XIII. reformed the calendar, by cutting off ten days between the 4th and 15th of October in that year, and calling the 5th day of that month the 15th. This alteration of the style was gradually adopted through the greater part of Europe, and the year was afterwards called the Gregorian year, or New style.

In this country, the method of reckoning according to the New style was not admitted into our calendars until the year 1752, when the error amounted to nearly 11 days, which were taken from the month of September, by calling the 3d of that month the 14th.

The error amounting to one whole day in about 130 years (by making every fourth year leap-year,) it is settled by an act of parliament that the year 1800, and the year 1900, which, according to the rule above given, are leap-years shall be computed as common years, having only 365 days in each; and that every four hundredth year afterwards shall be a common year also.

If this method be adhered to, the present mode of reckoning will not vary a single day from true time in less than 5,000 years:

The *beginning* of the year was also changed, by the same act of parliament, from the 25th of March to the 1st of January. So that the succeeding months of January, February, and March, up to the 24th day, which would, by the Old style, have been reckoned part of the year 1752, were accounted as the first three months of the year 1753. Hence we see such a date as this, January 1, 1757-8, or February 3, 1764-5; that is, according to the *Old* style it was 1764, but according to the *New*, 1765, because now the year begins in January instead of March.

CHAPTER XXXV.

THE TIDES.

The oceans, which cover more than one half of the globe, are in continual motion; they ebb and flow perpetually, and these alternate elevations and depressions are called *the tides*, or *the flux and reflux of the sea.*

The ancients considered the ebbing and flowing of the tides as one of the greatest mysteries in nature, and were utterly at a loss to account for it. Galileo and Descartes, and particularly Kepler, made some successful advances towards ascertaining the cause; but Sir Isaac Newton was the first who clearly pointed out the phenomenon, and showed what were the chief agents in producing these motions.

The tides are not only known to be dependent upon some fixed and determinate laws; but the true cause of their agitation is demonstrated to be the attraction of the sun and moon, particularly the latter; for as she is so much nearer the earth than the sun, she attracts with much greater force than he does, and consequently raises the water much higher; which, being a fluid, loses, as it were, its gravitating power, and yields to their superior force.

That the tides are dependant upon some known and determinate laws, is evident from the exact time of high water being previously given in every ephemeris, and in many of the common almanacs.

The moon comes every day later to the meridian than on the day preceding, and her exact time is known by calculation; and the tides in any and every place, will be found to follow the same rule; happening exactly so much later every day as the moon comes later to the meridian. From this exact conformity to the motions of the moon, we are induced to look to her as the cause; and to infer that those phenomena are occasioned principally by the moon's attraction.

If the earth were at rest, and there were no influence from either sun or moon, it is obvious from the principles of gravitation, that the waters in the ocean would be truly spherical, as plate XVI. fig. 1; but daily experience proves that they are in a state of continual agitation.

If the earth and moon were without motion, and the earth covered all over with water, the attraction of the moon would raise it up in a heap in that part of the ocean to which the moon is vertical, and there it would, probably, always continue, as plate XVI. fig. 2; but by the rotation of the earth upon its axis, each part of its surface to which the moon is vertical is presented to the action of the moon, and thus are produced two floods, and two ebbs.

In this supposition we have omitted to take notice of the sun's influence.

The attractive power of the sun is to that of the moon as *three to ten;* hence, when the moon is at change, the sun and moon being in conjunction, or on the same side of the earth, the action of both bodies is on the same ocean of waters; the moon raising it ten parts, and the sun three, the sum of which is thirteen parts, represented by plate XVI. fig. 4. Now it is evident that if thirteen parts be added to the attractive power of these bodies, the same number of parts must be drawn off from some other parts, as at C and D. It will now be *high water* under the moon at A, and *low water* at C and D.

The attractive power of the sun, according to some authorities, is to that of the moon as *two* to *ten*, or *one-fifth*, and according to others as *one-third*.

Those parts of the earth where the moon appears in the horizon, as at C and D, will have *low water;* for as the waters in the zenith and nadir (A and B) rise at the same time, the waters adjacent will press towards those places to maintain the equilibrium; and to supply the place of those, others will move the same way, and so on; hence at the places 90° distant (C and D) the waters will be lowest.

It is evident that, the quantity of water being the same, a rise cannot take place at A and B, without the parts C and D being at the same time depressed; and in this situation the waters may be considered as partaking of an *oval form*.

CHAPTER XXXVI.

THE TIDES, CONTINUED.

It has been already shown, under the article gravitation, that the power of gravity diminishes as the square of the distance increases; therefore not only those parts of the sea immediately *below* the moon must be attracted towards it, and occasion the flowing of the tides there, as at A, fig. 4; but a similar reason occasions the flowing of the tides in the nadir, or that part of the earth diametrically opposite to it, as at B, for in the hemisphere farthest from the moon, the parts being less attracted than those which are nearer, gravitate less towards the earth's centre, and consequently must be higher than the rest; and *as every portion of the earth will pass twice through the elevated*, and *twice through the depressed parts, two tides will be produced each day.*

It has been otherwise thus explained: All bodies moving in circles have a tendency to fly off from their centres; now as the earth and moon move round the centre of gravity, *that part of the earth* which is at any time *turned from the moon*, would have a *greater centrifugal force* than the *side next her*. At the earth's centre, the centrifugal force will balance the attractive force; therefore as much water is thrown off by the centrifugal force on the side which is turned *from* the moon, as is raised on the side next her by her attraction.

If the tide be at high water mark in any point or harbour that lies open to the ocean, it will presently subside and flow back for about six hours, and then return in the same time to its former situation, rising and falling nearly twice a day, or in the space of somewhat more than twenty-four hours.

The interval, however, between its flux and reflux is not precisely six hours, but about 12 minutes and ½ more, so that the time of high water does not happen at the same hour, but is above ¾ of an hour later every day for about 30 days, when it again recurs as before.

If the moon were stationary, there would be two tides every twenty-four hours, but as that body is daily proceeding from west to east in her orbit above 12°, the earth must make more than a complete revolution on its axis, before the same meridian is in conjunction with the moon. And hence, every succeeding day the time of high water will be above ¾ of an hour later than on the preceding.

For example: If it be high water to day at *noon*, it will be low water at 12 and ½ minutes after six in the evening; and, consequently, after two changes more, the time of high water the next day will be above ¾ of an hour *after* noon: the day following above ½ past one;—the day after that above ¼ past two, and so on.

Again: Suppose at any place it be high water at three in the afternoon upon the day of the new moon, the following day it will be high water about ¾ after three;—the day after about ½ past four, and so on till the next new moon.

Not only when the sun and moon are in conjunction, or at the change, but *when in opposition, at the full, the tides are at the highest*, as in fig. 6. For when the moon is at full, ten parts of water are raised from that side of the earth next her, by her attractions; and as the side which is next her is opposite to the sun, three parts must be thrown off by his centrifugal force, the sum of which will be thirteen parts next the moon.—Again, from the side opposite to the moon and under the sun, ten parts are thrown off by her centrifugal force, and three raised by his attraction, making thirteen, the same as before.

If there were no moon, the sun, by his attraction, would raise a small tide on the side of the earth next him; and it is evident that the tides on the opposite side would be raised as high by the centrifugal force; for the sun and earth, as well as the earth and moon move round their centres of gravity.

The highest tides happen when the sun and moon are either in conjunction (fig. 4,) or opposition (fig. 6,) and these are called *Spring Tides;* but when the moon is in her quarters (as fig. 5,) the influences of the sun and moon counteract each other; that is, they act in different directions; the attraction of the one *raising* the waters, while that of the other *depresses* them. The moon of herself would raise the water *ten parts* under her, but the sun, being then in a line with low water, his influence keeps the tides from falling so low there, and consequently from rising so high under and opposite the moon. His power, therefore, on the low water being *three parts,* leaves only *seven parts* for the high water, under and opposite the moon. These are called *Neap Tides.*

CHAPTER XXXVII.

THE TIDES, CONTINUED.

The tides are known to rise higher at some seasons than at others: for the moon goes round the earth in an elliptic orbit, and therefore she approaches nearer to the earth in some parts of her orbit than at others. When she is nearest, the attraction is the strongest, and consequently it raises the tides most: and when she is farthest from the earth, her attraction is the least, and the tides are the lowest.

From the above theory, it may be supposed that the tides are at the highest when the moon is on the meridian, or due north and south. But we find that in open seas, where the water flows freely, the moon has generally *passed the north or south meridian about three hours, when it is high water.* For even if the moon's attractions were to cease when she had passed the meridian, the motion of ascent communicated to the water before that time, would make it continue to rise for some time after.

Much more must it do so when the attraction is not withdrawn, but only diminished: as a little impulse given to a moving ball will cause it to move still farther than it otherwise could have done. And experience shows that the heat of the day is greater at three o'clock in the afternoon than it is at twelve; and it is hotter in July and August than in June, because of the increase made to the heat already imparted.

The tides, however, answer not always to the same distance of the moon from the meridian, at the same place; but are variously affected by the action of the sun, which brings them on *sooner*, when the moon is in her *first* and *third* quarters; and keeps them back *later*, when she is in her *second* and *fourth.* Because in the former case the tide raised by the sun alone would be earlier than the tide raised by the moon, and in the latter case later.

The *greatest spring tide* will happen when the moon is in *perigee*, if other things are the same; and the succeeding spring tide when the moon is in *apogee* will be the least. But as the effect of a luminary is greater the nearer it approaches to the plane of the equator, and as the earth is nearer the sun in winter than in summer, and still nearer in February and October than in March and September; the *greatest tides* happen not till some time *after the autumnal* equinox, and return a little *before the vernal.*

In open seas the tides rise but to very small heights, in proportion to what they do in wide-mouthed rivers opening in the direction of the stream of tide. For in channels growing gradually narrower, the water is accumulated by the contracting banks. At the mouth of the Indus, the water rises and falls full thirty feet, and in the bay of Fundy seventy feet.

The tide in the above instance has been compared to a moderate wind, which, though not much felt in an open plain, may yet appear with a strong and brisk current in a street, and become still more powerful as the more confined.

Though the tides in *open seas* are at the highest about *three hours* after the moon has passed the meridian, yet the waters, in their passage through shoals and channels, and by striking against capes and head lands, are so retarded that, to different places, the tides happen at all distances of the moon from the meridian, consequently at all hours of the lunar day.

The tide raised by the moon in the German Ocean, when she is three hours past the meridian, takes twelve hours to come thence to London bridge, where it arrives by the time that a new tide is raised in the ocean.

There are no tides in lakes, because they are generally so small that, when the moon is vertical, she attracts every part of them alike, and by rendering all the waters equally light, no part of them can be raised higher than another. The Mediterranean and Baltic seas have very small elevations, because the inlets by which they communicate with the ocean are so narrow, that they cannot, in so short a time, either receive or discharge enough, sensibly to raise or sink their surfaces.

Air being lighter than water, it cannot be doubted that the moon raises much higher tides in the air than in the sea.

Although it has been stated that the highest tides are produced by the conjunction and opposition of the sun and moon, yet their effects are not *immediate;* the highest tides happen not on the days of the full and change, neither do the lowest tides happen on the days of their quadratures. But on account of the continuation of motion these effects are greatest and least, *some time after* their forces are. So that the greatest *spring tides* commonly *happen two days after the new and full* moons ; and the least *neap tides two days after the first and third quarters.*

For if the greatest elevation immediately under the moon, points to one side of the equator, the opposite greatest elevation points as much to the other side. And those places which are on the same side of the equator with the luminary, approach nearest to the greatest elevation when she is above the horizon, than to the greatest opposite elevation when she is below the horizon.

This inequality is greatest when the sun and moon have the greatest declination. It is also greatest in places most remote from the equator. The nearer the place approaches to the poles, the farther it is removed from the greatest elevation on the opposite side of the equator. Thus the less tide is continually diminishing, till at last it entirely vanishes, *and leaves only one tide in the day.*

Hence it is found by observation, that there is *only one tide in twenty-four hours*, in all places *in the polar regions* in which the moon is either always above or always below the horizon, during the whole rotation of the earth about its axis

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CHAPTER XXXVIII.

THE PRECESSION OF THE EQUINOX.

It has been already observed, that the form of the earth is that of an oblate spheroid; for by the earth's motion on its axis there is more matter accumulated all around the equatorial parts than any where else on the earth.

The sun and moon by attracting this redundancy of matter bring the equator sooner under them, in every return towards it, than if there were no such accumulation. Therefore if the sun sets out from any star, or other fixed point in the heavens, the moment when he is departing from the equinoctial (or from either tropic) he will come to the same equinox (or tropic) again 20 minutes, $17\frac{1}{2}$ seconds of time (or which is equal to 50″ of a degree) before he arrives at the same fixed star or point from which he set out. For the equinoctial points *recede 50″ of a degree westward* every year contrary to the sun's annual progressive motion.

To prove that 20 *minutes* $17\frac{1}{2}$ *seconds of time* are equal to 50″ *of a degree*, it must be recollected that the sun goes through the whole ecliptic of 360°, in $365\frac{1}{4}$ days, which is not quite one degree each day, but 59′ 8″, (or 52″ less than a degree.) Therefore, if by the rule of proportion we say, as 59′ 8″ : 24 hours : : 50″, the result will be 20 minutes $17\frac{1}{2}$ seconds, nearly. That the sun has a *daily* apparent motion in the ecliptic from west to east is evident from comparing the sun's right ascension every day with that of the fixed stars lying near him. For the sun is found constantly to recede from those on the west, and approach those on the east; hence his apparent annual motion is found to be from west to east.

When the sun arrives at the same equinoctial or solstitial point, he finishes what is called the *tropical year;* which, *according to some authorities*, is found to contain 365 days, 5 hours, 48 minutes, 48 seconds (see page 4,) and when he arrives at the same star again, as seen from the earth, he completes the *sidereal year*, which contains 365 days, 6 hours, 9 minutes, $14\frac{1}{2}$ seconds. The sidereal year is therefore 20 minutes, $17\frac{1}{2}$ seconds longer than the solar or tropical year, and 9 minutes, $14\frac{1}{2}$ seconds longer than the *Julian* or *civil* year, which is 365 days, 6 hours. So that the civil year is almost a mean between the sidereal and tropical.

According to Professor Vince, a *sidereal year* is 365 days, 6 hours, 9 minutes, 11 seconds, .5; and a *tropical year* 365 days, 5 hours, 48 minutes, 48 seconds.

As the sun describes the whole ecliptic, or 360° in a tropical year, he moves 59′ 8″ of a degree every day at a mean rate; which is equal to 50 seconds of a degree in 20 minutes $17\frac{1}{2}$ seconds of time: therefore he will arrive at the same equinox or solstice when he is 50″ of a degree *short of the same star* or fixed point in the heavens, from which he set out the year before. So that, with respect to the fixed stars, the sun and equi noctial points fall back (as it were) 30° in 2,160 years This will make the stars *appear to have gone* 30° *forward*, with respect to the signs in the ecliptic in that time: *for it must be observed, that the same signs always keep in the same points of the ecliptic, without regard to the place of the constellations.*

50″ short in one year are = 1° short in 72 years. For in a degree are (60 × 60) 3,600″, which divided by 50″, will give 72.—And 1° less in 72 years = 30° or *one whole sign* in 2,160 years. To explain this by a figure; suppose the sun (plate XVII. fig. 1st,) to have been in conjunction with a fixed star at S, on the first degree of Taurus, 342 years before the birth of Christ, or about the 15th year of Alexander the Great; then making 2,160 revolutions through the ecliptic, he will still be found at the end of so many *sidereal years*, again at S: but at the end of so many *Julian years*, he will be found at J, and at the end of so many *tropical years*, at T. in the 1st degree of Aries, which has receded back from S to T in that time, by the precession of the equinoctial points ♈ and ♎. The arc S T will be equal to the amount of the precession of the equinox in 2,160 years, at the rate of 50″ of a degree, or 20 minutes 17½ seconds of time annually, as above calculated

From the shifting of the equinoctial points, and with them all the signs of the ecliptic, it follows that *the longitude of the stars must continually increase.* Hence those stars which, in the infancy of astronomy, were in *Aries*, are now got into *Taurus;* those of *Taurus* into *Gemini*, as may be seen by inspecting the celestial globe. Hence likewise it is that the star which rose or set at any particular time of the year, in the times of *Hesiod*, *Eudoxus*, *Virgil*, *Pliny*, &c. by no means answers at this time to their descriptions.

By comparing the longitude of the same stars, at different times, the motion of the equinoctial points, or the precession of the equinoxes may be found.

Hipparchus was the first person who observed this motion, by comparing his own observations with those which Timocharis made 155

Fig. 1 *Epicyctoids*

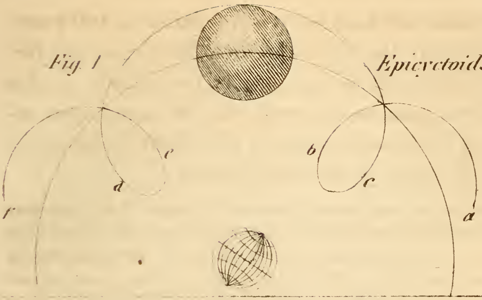
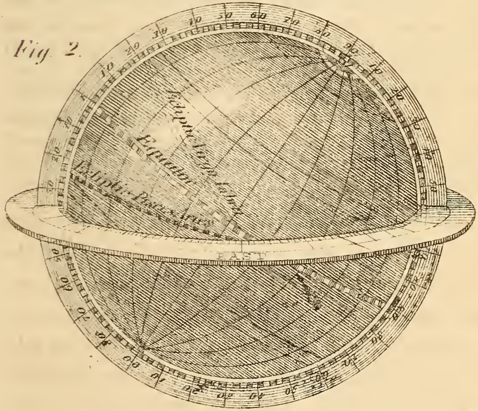


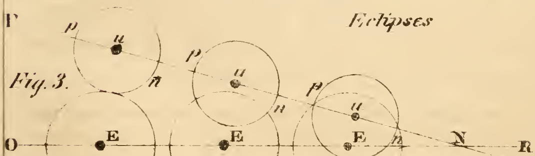
Illustration of the Harvest Moon

Fig. 2.



Eclipses

Fig. 3.



P. S. Duval lith. Phila

[illegible]

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[illegible]

years before. From this he judged the motion to be about 1° in about 100 years; but he doubted whether the observations of Timocharis were sufficiently accurate.—In the year 128 before Christ he found the longitude of Virgin's Spike to be 5 signs 24°, and in the year 1750 its longitude was found to be 6 s. 20° 21'. In the same year he found the longitude of the Lion's Heart to be 3 s. 29° 50', and in 1750, it was 4 s. 26° 21'. The mean of these gives 50''.4 in a year for the precession.

By comparing the observations of Albategnius, in the year 878, with those made in 1738, the precession appears to be 51'' 9'''.—From a comparison of fifteen observations of Tycho, with as many made by M. de la Caille, the precession was found to be about 50'' 20'''.

By proceeding to shift a whole *degree* every 72 years, and a whole *sign* every 2160 years, the equinoctial points will fall back through the whole of the 12 signs, and *return to the same points again* in 25,920 years; which number of years completes *the grand celestial period.*

From the creation to the year 1819, supposing it to be (4004 + 18 ?) = 5823 years, the equinoctial points have receded 2 s. 20° 51' 54''

CHAPTER XXXIX.

THE PRECESSION OF THE EQUINOX, CONTINUED.

Having thus noticed the *cause* of the precession of the equinoctial points, which occasions a slow deviation of the earth's axis from its parallelism, and thereby a change of the declination of the stars from the equator together with a slow apparent motion of the stars forward, with respect to the signs of the ecliptic, the phænomena may be explained by a diagram.

Let S O N A (fig 3, plate XVII.) be the axis of the earth produced to the starry heavens, and terminating in A, the present north pole in the heavens; E O Q the equator; T ♋ Z the tropic of Cancer, and V T ♑ the tropic of Capricorn; V O Z the ecliptic, and B O its axis, both which are immoveable among the stars. But as the equinoctial points recede in the ecliptic, the earth's axis S O N is in motion upon the earth's centre O, in such a manner as to describe the cone N O *n*, and S O *s*, round the axis of the ecliptic B O, in the time the equinoctial points move round the ecliptic, which is 25,920 years.

In that length of time the north pole of the earth's axis produced, describes the circle A B C D A in the heavens, round the pole of the ecliptic, which keeps immoveable in the centre of that circle. The earth's axis being 23½° inclined to the axis of the ecliptic, the circle A B C D A, described by the north pole of the earth's axis, produced to A, is 47° in diameter, or double the inclination of the earth's axis.

In consequence of this motion, the point A, which is at present the north pole of the heavens, and near to a star of the second magnitude in the tail of the constellation called the *Little Bear*, must be deserted by the earth's axis. And this axis moving backward a degree every 72 years, will be directed towards the star or point B in 6,480 years from this time: and in twice that time, or 12,960 years, it will be directed towards the star or point C, which will then be the north pole of the heavens; although it is at present 8½° south of the zenith of London, L.

Then the present positions of the equator and the tropics represented by the *black lines*, will be changed to those represented by the *dotted lines*. And the sun which in the diagram is over *Capricorn*, and makes the shortest days and longest nights to the northern hemisphere will then be over Cancer, and make the days longest and nights shortest.

It will then require 12,960 years more (or 25,920 from this time) to bring the north pole back quite round to the present point: and then, and not till then, will the same stars which now describe the equator, tropics, polar circles, &c. describe them again.

CHAPTER XL.

THE OBLIQUITY OF THE ECLIPTIC, ETC.

It may not be amiss to mention the method used by astronomers to determine the *obliquity of the ecliptic*; which is, by *taking half the difference of the greatest and least meridian altitudes of the sun.*

	°	′	″
Eratosthenes, 230 years before Christ, found the obliquity to be	23	51	20
Ptolemy, 140 years after Christ	23	51	10
Copernicus, in 1500	23	28	24
M. De la Lande, in 1768	23	28	0

Not to mention *many others*; and from all these united observations, it is manifest that *the obliquity of the ecliptic continually decreases.*

Comparing the numerous observations that have been made to ascertain the true obliquity, the mean of the several results gives about 50″ in a century. "We may therefore state," says Professor Vince, "The secular diminution of the obliquity of the ecliptic, at this time, to be 50″, as determined from the most accurate observations; and this result agrees very well with that deduced from theory."

CHAPTER XLI.

TO FIND THE PROPORTIONATE MAGNITUDES OF THE PLANETS.

To find the proportion that any planet bears to the earth, or that one globe bears to another, the diameter of each must be cubed, and the greater number divided by the less: the quotient will show the proportion that one bears to another: for *all spheres or globes are in proportion to one another as the cubes of their diameters.*

The cube of any number is the product of that number multiplied *twice* into itself. Thus, the cube of 2 is 8; for 2 multiplied by 2 makes 4, and 4 multiplied again by 2 makes 8.—So the cube of 3 is 27; for $3 \times 3 \times 3 = 27$.

If the diameter of the sun, as some assert, be 893,522 miles: and of the earth 7,920 miles; then the cube of 893,522 is 713371492260872648, and of 7,920 is 496793088000, and the greater number divided by the less will give 1435952, and so many times is the bulk of the sun greater than that of the earth.

TO FIND THE PLANETS' DISTANCE FROM THE SUN.

By the transits of Venus (already explained, page 101,) the distance of the earth from the sun has been found to be about 95,000,000 of miles; and by knowing the earth's distance, the distances of the other planets are calculated.

Kepler, a great astronomer, discovered that all the planets are subject to one general law, which is, that the *squares of their periodical times are proportional to the cubes of their distances from the sun.* And this law was fully demonstrated by Sir Isaac Newton.

By their *periodical times* is meant the time they take in revolving round the sun: thus the periodical time of the earth is 365½ days; that of Venus, about 224¾ days; that of Mercury nearly 88 days.

Therefore, if we would find the distance of Mercury from the sun, we say, as the square of 365 days is to the cube of 95,000,000, so is the square of 88 days to a fourth number, which will be the cube of its distance. And if the cube root of this number be extracted, the answer will be nearly 37,000,000 of miles

Thus the square of 365=133225; the cube of 95=857375; and the square of 88=7744. Therefore, as 133225 is to 857375, so is 7744 to 49836, the *cube* of the mean distance of Mercury. And if the *root* of 49836 be extracted, it will be more than 36¾,=the mean distance of Mercury from the sun in millions of miles.

QUESTIONS

FOR EXAMINATION IN ASTRONOMY.

Chapter I.

What is Astronomy?—Of how many parts does it consist, and what are they?—What does descriptive Astronomy treat of?—And what does physical?—What is a circle?

What is the circumference sometimes termed?

What is the radius?—What the diameter of a circle?

Name the proportion between the diameter and radius.

What is an *arc* of a circle?—What is a chord of a circle?—Does a chord *necessarily* divide a circle into two unequal or equal parts?—What is a semicircle?

By what other name is a semicircle sometimes called?

What is a quadrant?

What is the quarter of the periphery of a circle sometimes termed?

Into how many parts are all circles supposed to be divided?—How are degrees marked?—How minutes and seconds?—Mention the number of degrees in a semicircle and in a quadrant.—What is an angle?—Which is the angular point?—Which are the legs of a right-angled triangle?—What is a right angle?—What is the measure of a right angle?—What is an acute, what an obtuse angle?—Define what are parallel lines.—What is a globe or sphere?—What is a spheroid?—What is a great circle of a sphere?—What is a small circle of a sphere?—What is the diameter of a sphere to any great circle termed?—What are the extremities of the diameter called?

What distance is the pole of a great circle from every part of the diameter? and for what reason?—Into what parts, and whether equal or not, do two great circles divide each other? and why?

What is the axis of the earth?

Chapter II.

Fully define the science of Astronomy.

What is the general opinion of Astronomers with respect to the different systems of the universe?

What are the sun and moon termed ?—How are stars distinguished —Whence do the planets receive their light ?—What attendants have they ?—Is there any other order ?—What are the names of the planets, and which are the Asteroids ?—What are these called, and how many moons are there ?—To what planets do they belong ?

The Sun.

What is the Sun ?—What his form, diameter, and circumference ?

What is the sun's diameter equal to ?

What is his distance from the earth ; and how much larger ?

What was the sun formerly thought to be ?

What does Dr. Herschel suppose the sun to be ?

What can be seen on the sun's surface ?

What is meant by maculæ and faculæ ?

What new opinion is formed respecting it ?

How many motions has the sun, and what are they ?—What does the sun's motion about its axis render it ?

Chapter III.—*Mercury.*

Name the smallest and nearest planet to the sun ?—What is his diameter, and in what time does he revolve about the sun ?—At what distance, and at what rate does he move in his orbit ?

What proportion do the mean distances of Mercury and the earth from the sun bear to each other ?

What appearance has Mercury ?

How will the sun's diameter appear, if viewed from Mercury, and how much greater is the light and heat he receives than that of the earth ?

In what manner does he change his phases ?

How does this planet appear to us ?—How is it known that he does not shine by his own light ?

When the orbit of this planet is between that of the earth and the sun, what is it denominated ?

When did the last transit of this planet happen, and when will the next ?

Venus.

What is the next nearest planet to the sun, and how is she distinguished ?—What is her distance from the sun ?—In what time does she complete her annual revolution ; and in what her rotation about her axis ?

What do astronomers make a complete rotation to be?

What is her magnitude; what her diameter, and at what rate does she move in her orbit?—Is her quantity of light and heat greater than that of the earth?—What is her appearance as seen by the naked eye; and what, when viewed through a telescope?—What is Venus denominated when seen by us westward of the sun; and what when eastward?—Is there any difference in her seasons, and why?

Does she always appear of the same size, and what do her variations demonstrate?

Are there any transits of Venus, and how often do they occur?

When was the last seen, and when will the next happen?—What have astronomers ascertained by this phenomena?—Who was the first person that predicted the transit of Venus and Mercury?—When was the first time Venus was ever seen upon the sun, and by whom?

Chapter IV.—*The Earth.*

Which is the third planet from the sun, what its mean distance, its diameter, and its circumference?

What would be the appearance of the Earth from the planet Venus?

What are the Earth's motions?—At what rate does it move in its orbit?—In what time does it perform an entire revolution, and what does a complete rotation form?

What is the more exact time of its annual motion?—By what is time divided?—On what does the former, and on what does the latter depend?

What is the true form of the Earth?

What form was the Earth formerly supposed to be? and what since proved to be?

Of what service is the earth to the moon, and of what size does she appear, viewed from the moon?

The Moon.

To what planet is the Moon a satellite?—In what time does it revolve in its orbit?—What is the mean distance of the Moon from the earth, and at what rate does she move in her orbit?—What is her diameter. and bulk?—In what time is her rotation on her axis performed, and what the length of her day and night?—How often does she revolve round the earth in a year?—What is the length of her year?—What are the phases of the Moon?—Whence does the Moon receive her light?—What enlightens that part of the Moon which is turned from the sun ?—Has the Moon any diversity of seasons ?—What do the shades which appear on the face of the Moon result from ?

What were the former opinions respecting the mountains of the Moon ?—What are the present ?—What else is observed in it ?—When can the irregularity of the Moon's surface be most distinctly seen ?

When is the Moon invisible to us ? and what is her first appearance called ?

Which hemisphere of the Moon is never completely dark, and why ? —How long is the other hemisphere enlightened ?

Is the moon thought to be inhabited ?—What is supposed concerning seas in the Moon, or her atmosphere ?

Chapter V.—*Mars.*

Which is the next planet to the earth, and how is he known in the heavens ?—What is his distance from the sun, and what the length of his year ?

Has the cause of his dusky red colour been ascertained ?—At what rate does he move in his orbit ?—In what time is the diurnal motion of this planet performed ?—What is his diameter ?—What portion of light does he enjoy ?

What is the mean distance of Mars from the sun, in regard to our earth ? How is the diurnal motion of Mars ascertained ?—Who first discovered them, and what has been since determined from them ?

How does Mars appear when viewed through a telescope ?—Has he any satellites ?

How does he appear when opposite the sun ? and what does it prove ? —Is the earth or sun in the centre of his motion ?

Asteroids.

Have any planets been discovered between the orbits of Mars and Jupiter ?—What are their names ?—Which is the nearest to Mars ?—What is its mean distance from the sun ?—How soon is its revolution through its orbit performed ?—How many degrees does it incline to the ecliptic ?

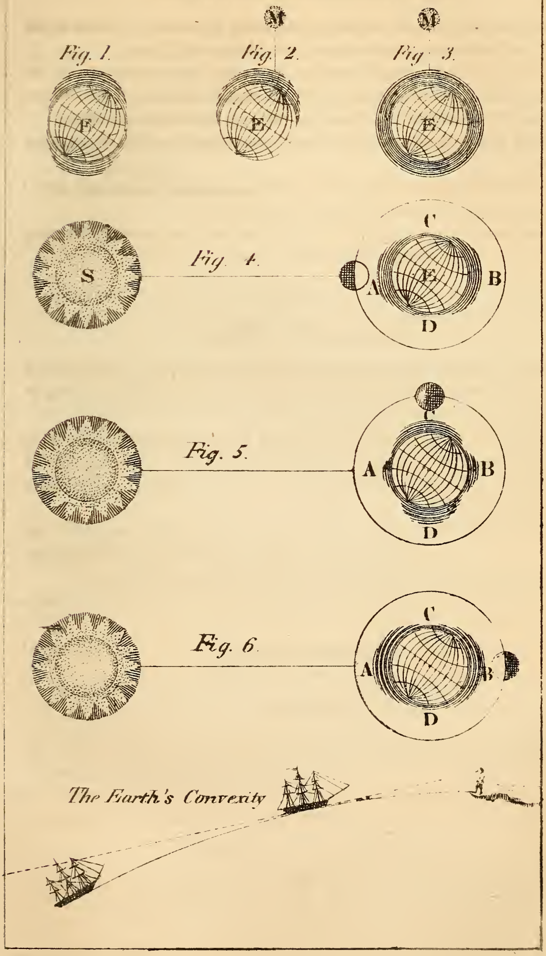
By whom was Vesta discovered, and when ?

What is the mean distance of Ceres from the sun ?—What its time of revolution, its diameter, and its inclination to the ecliptic ?

By whom was Ceres discovered, and when ?

What is the mean distance of Pallas from the sun ?—What is the time

Illustration of the Tides



of its revolution ?—What its diurnal motion ?—How great is its inclination to the ecliptic ?—What is its diameter ?

By whom was Pallas discovered, and when ?

What is the mean distance of Juno from the sun, and what is its size ? —In what time is its revolution round the sun performed ?—What its diameter ?—What is the inclination of its axis to the ecliptic ? and what does it appear like ?

By whom was it discovered ?

Chapter VI.—*Jupiter.*

Between what planets does the orbit of Jupiter lie ?—What his magnitude ? and how is he distinguished ?—What is the distance of Jupiter from the sun ?—What his mean distance from the sun ?—How much farther than the earth, and what proportion of light and heat does he receive ?—What is the diameter of Jupiter, and how much larger is he than the earth ?—What proportion does his year bear to ours ?—In what time does he make his revolution round the sun, and at what rate does he move in his orbit ?—In what time does Jupiter revolve on his axis ? —Does his equatorial exceed his polar diameter ?—Does his axis incline to his orbit ?—What difference in his seasons ? and what variation in his days and nights ?—What is the length of his day and night ?—What appearance has he viewed through a telescope ?

To what variations are his zones or belts subject, and what are they supposed to be ?—Are they supposed to adhere to the body of the planet ?

Jupiter's Satellites.

How many satellites has this planet ?—In what time does the nearest make a revolution ?—What the most distant ?—By whom were they first discovered ?—What were they first taken to be ?—What are the periodical times of the first, second, third, and fourth ?—To what purpose have their eclipses been applied ?

Chapter VII.—*Saturn.*

What was Saturn formerly thought to be ?—What is his appearance ? —What his mean distance from the sun ?—What light and heat has he in proportion to the earth ?—What proportion does his light bear to that of our full moon ?—What is the diameter and magnitude of Saturn ?—In what time does he perform his revolution in his orbit ?—

How many miles does he travel in an hour?—In what time does he revolve about his axis?—Who ascertained it?

Satellites of Saturn.

How many Satellites or moons is Saturn encompassed with?—Of what use are they supposed to be?—What distance is the nearest, and what is its breadth?—Of what breadth is the outer ring?—What is the space between them?—What is it conjectured they are composed of?—In what time does the ring revolve about the planet?

Chapter VIII.—*Uranus.*

Which is the most remote planet yet discovered?—What appearance has he to the naked eye?

When can it be best perceived?—Who discovered this planet, and when?—Why is it named the Georgium Sidus?—What is it called by astronomers?—What other names does it bear?

What is the distance of this planet from the sun?

What is the distance given by some authors?—What light and heat does he receive, compared with the earth?

In what time does he perform his annual revolution, and at what rate does he travel?—What is his diameter?

The Herschel's Satellites.

How many Satellites has Herschel?

In what time does the nearest perform his revolution? and in what the most remote?

Of what use are they supposed to be?

The Proportional Magnitude and Distance of Planets.

How much larger is the Earth than Mercury, Venus, Mars, or Pallas?—How much larger than the Earth is Jupiter, Saturn, and Herschel?—How do astronomers express the mean distances of the planets?—What distance from the sun may the different planets be estimated at?—How a e the distances calculated?

Chapter IX.—*Comets.*

What are Comets thought to be? and what direction do their orbits take?

Are they supposed to be adapted to the habitation of animated be ings?—Whence is the name of Comet derived?—What are their tails supposed to be?—When could it happen that the tail of a Comet could come near our atmosphere?—Of how many Comets were the periods thought to be distinctly known?—When did the first appear? when the second? and when the third?—What is the greatest distance of this Comet from the sun? and what the least distance from the sun's centre?—At what rate does it travel?

How many miles in diameter was the head of the Comet of 1807 ascertained to be, and what that of 1811?—Of what nature are Comets? —What did Sir Isaac Newton estimate the head of that Comet to be, seen by him in 1680?

Whence are we authorized to conclude that Comets receive their light?

Of what do comets consist?—What is the nucleus, what the head and what the coma?—How long was the tail of the Comet of 1807 ascertained to be, and how long that of 1811?—What its distance from the sun, and what from the earth?

Chapter X.—*The Fixed Stars.*

What are the heavenly bodies beyond our system called?

What is it probable they are?

By what light do the fixed stars shine?

How much nearer are we to some stars at one time, than at another.

What is the distance of Sirius, or the Dog-star, from us?—In what time would a cannon ball reach us from that star?

How much farther from us than the sun is the nearest fixed star?—Have any been observed to revolve on their axis?

What is it probable the fixed stars are?—Into how many magnitudes are they usually classed?—What are the largest called?—What the smallest?—How many are visible to the naked eye at one time?

What is the occasion of the stars appearing to us innumerable?

Do not some of the fixed stars, when viewed through a telescope appear double or treble?—What are clusters of stars called?—Which is the most remarkable of the clusters called nebulæ?—What has Dr Herschel remarked concerning the Milky Way?

What is observed of the Magellanic clouds?—Have not a greater number of stars been observed since the use of telescopes?

How are planets distinguished from fixed stars?

What is thought to occasion the twinkling of the fixed stars?

Are all stars that were known to the ancients, now to be seen?—And are not some now seen that were not noticed by them?

By whom is the most ancient observation of a new star?—Which the first we have any accurate account of?

Have not some stars alternately appeared and disappeared? What have other stars been subject to?

What star was discovered in 1600?—What were its different appearances?—What was discovered respecting β Lyræ?

What appearance has the heavens to a spectator in any part of the universe?—What proof have we of this?—If transplanted to a planet belonging to Sirius, how would that star and our sun appear to us?

What is the vulgar error respecting the stars?

Chapter XI.—*Constellations.*

Into what did the ancients form the stars?

For what purpose were the constellations formed?

What was the ancient, and what the present number of the constellations?—By what are the heavens usually distinguished?—What is the number of the constellations in the northern hemisphere?—What in the southern? and what in the zodiac?—What are the stars called not comprehended in these.—Name the northern constellations, and the southern.—Repeat the zodiacal constellations. How are some particular stars distinguished?— How are others denoted?

Chapter XII.—*Different Systems.*

What is the system called which has been described?—By whom was it formerly taught?—By whom revived?—What did Ptolemy suppose?

What are epicycloids?

What system did the Egyptians receive?—Who at length adopted the Pythagorean?—How did Copernicus place the sun and planets?—What system did Tycho Brahe endeavour to establish?—By whom was the solar system first taught?—By whom revived?—By whom confirmed?—And who at length fully established it?

CHAPTER XIII.—*On the Motions of the Planets.*

How would the planets appear to move if seen from the sun?—How do they appear to move as seen from the earth?

Give some illustration of the motions of the planets.

When is their motion direct?—When retrograde?—When stationary?

Inferior and Superior Conjunctions of the Planets.

What is a planet in its inferior conjunction?—When in its superior? —What planets have alternately a conjunction and an opposition?—And when?—In which case do they rise and set nearly with the sun? —When is it the reverse?—Does the appearance of a planet vary if viewed through a telescope?—When is Venus seen with nearly a full face?—When only half enlightened?

When can Mercury and Venus be seen in their inferior conjunction?

What planets do these appearances refer to?

CHAPTER XIV.—*The Plane of an Orbit, Planets, Nodes, &c.*

What circle does the earth describe as seen from the sun?

In what different signs do the earth and sun appear?

What is understood by the *plane of a circle?*

Give some illustration.

In what do the orbit of the earth and the ecliptic vary?

Give some illustration.

Do the orbits of the planets vary from the ecliptic?—What is meant by the obliquity of their orbits?—Demonstrate it by the figure.—What is meant by the line of the nodes?—What by the ascending, and what by the descending node?—What is really meant by the terms *plane* and *orbit?*

Transits of Mercury and Venus.

Define by plate VIII. fig. 1, and by plate XIV. fig. 6, the transits of Venus or Mercury.—Are there great variations in the magnitude of Venus, as seen from the earth?—Demonstrate this by the figure, plate VII. fig. 1.—What is the least distance of Venus from the earth?—What the greatest?

Explain the phases of Venus, in her orbit, by the figure.

Chapter XV.—*The Ecliptic, Zodiac, Equator, &c.*

What is the ecliptic?—Name the most conspicuous stars near the ecliptic.

From what stars is the moon's distance calculated?—Why is the ecliptic so called?

Whence arises the obliquity of the ecliptic?—What are the *points* of intersection called?—What are the *times* of intersection called?—What is the zodiac?

Whence is the term zodiac derived?

Give the names and characters of the twelve signs?—Which are the northern signs?—Which the southern?—Which are called the ascending?—Which, descending?—To what do the signs correspond?—How much of the ecliptic does the earth pass over each day?—How much each month?—How many degrees in a sign?—And why?—What is the terrestrial equator?—What is its distance from the poles? -How does it separate the globe?—What is the celestial equator?

Of the Ephemeris.

What does the *first* column of the Ephemeris show?—What the second?—What the third?

If you know the time of the sun's rising, how do you know the time of its setting, and *vice versa?*

What does the fourth column show?

What and when is the sun's greatest declination?—When will he have no declination?—What is meant by declination?

When does an astronomical day begin?—What do the three next columns contain?—What is meant by *southing*?—How often and when does the moon come to the meridian with the sun?

How much later, one day with another, does the moon culminate?

What does the eighth column show?—What is the adjusting of time called?

How often and at what times are the clock and dials together?

How are the clocks, &c. regulated?—What does the first short column?—What the second short column?—What the five following columns?—What is meant by the *heliocentric* longitude?—And what by the *geocentric*?

Define the heliocentric and geocentric longitudes by the figure.—Which longitude is given in page 9 of the Ephemeris?

Explain the column for daylight.—What is meant by the *latitude* of a planet?—And what columns show the latitude?—How is the longitude of a heavenly body usually expressed?—Which of the columns speak of the rising or setting of a planet?—Why not of both?

Chapter XVI.

What is a degree?—What is the measure of an angle?

Explain this by fig. 3, plate IX.

What are the poles?—What parts of the heavens appear motionless?—And what part appears to have the greatest motion?—What are the tropics?—What their distances from the equator?—What are the polar circles?—What their distance from the poles?

Why is the distance of the polar circles fixed at that number of degrees from the poles?

Why are the meridians so called?—How many meridians are usually drawn on the globes, and why?—Are these all that can be represented?

Explain this by fig. 3, plate IX.

What is meant by longitude?—Through what place does the first meridian pass?—How many degrees are equal to an hour?—What places are *before* London, in time, and what *after?*—How do you reduce longitude to time?

Give the reason why 15 degrees are equal to an hour; and 30 degrees to two hours, &c.—If 12 o'clock at London, what are the times at Barbadoes, at St. Petersburgh, and at Calcutta.

How is time turned into longitude?—What is meant by the latitude of a place?—What by the latitude of a heavenly body?—What are the colures?—How many zones are there, and what are they?—What are the solstitial points? And why so called?—What are the equinoctial points? And why so called?

Chapter XVII.—*Planets' orbits Elliptical.*

What are the orbits of the planets termed?—Illustrate this by figures 2, 3, and 5, of plate VIII.—When is a planet said to be in its *perihelion*, and when in its *aphelion?*—And when at its middle or mean distance?—What is termed the eccentricity of its orbit?

Attraction of Gravitation.

What is meant by attraction?

What is attraction of magnetism?—What attraction of electricity?—What of cohesion?

What is attraction of gravitation? In what proportion is this attraction?—By what kind of attraction does the sun affect the earth, and the earth the moon?

Upon what principle does the stone fall to the earth—and the waters of the ocean gravitate, &c.

Repeat one of the laws of attraction.—Illustrate this by the figures 4 and 5 of plate X.—What is the second law of gravity?—Do equal magnitudes imply equal quantities of matter?—With what proportion does the sun attract the earth? And why?—Explain this otherwise, by boats of equal bulk.

Chapter XVIII.—*Of Attractive and Projectile Forces.*

What power counteracts that of attraction?—What would be the effect of rectilineal motion?—Of what are the planets' motions compounded?

Explain this by some projectile force.—What, if a ball be thrown from the hand?

What united forces retain the planets in their orbits?

Explain the difference of a *circular* motion and a *straight line*.—Give a further explanation by the figure 4, plate VIII.

What results from the two forces being equal?

What would result if either power were to cease acting?

By what laws are the secondary planets governed?—Why are the planets' orbits not true circles?

Explain by the figure, what is meant by equal portions in equal times—And by unequal portions in equal times.

What power will a double velocity balance?—Demonstrate this by the figure.—What is meant by equal areas in equal times?—What results from the comets' orbits being so very elliptical?

Suppose a body to receive two different impulses, what would be its direction?—Epxlain this by the figure.

Chapter XIX.—*The Centre of Gravity.*

What is the centre of gravity?—Explain this by figure 6, plate X.

If the earth were the only attendant on the sun, what motion would the *sun* have?

What, if all the planets were on the same side of him?—Are the so condaries governed by the same laws?—What is supposed of every system in the universe?

The Horizon.

What is the horizon?—To what does the *rational* horizon apply?—Explain this by fig. 2, plate IV.

How is this horizon represented on the artificial globe?

What does the *sensible* horizon respect?—How is its extent varied?

Refer to the figure.—What is the extent of view, to an eye elevated five feet? And to one elevated twenty feet?—How do you mark the difference of the two horizons?

Why do persons on the sensible horizon see the heavenly bodies when on the rational?

What proportion does the earth's semi-diameter bear to the sun's distance?—And what is the result?—What proportion does the earth's semi-diameter bear to the moon's distance.

Chapter XX.—*Day and Night.*

What is the cause of the succession of day and night?—Illustrate this by fig. 2, plate IV.—How much of a sphere does the sun illumine at one time?—How much of the heavens can a spectator behold at one time?

Explain the *apparent* motion of the heavenly bodies, by some familiar motions on our earth.

How are the apparent motions of the whole starry firmament accounted for?

What results from the earth's motion to persons in the latitude of London?—What, to those on the equator?

What points in the heavens keep the same positions?—Why are stars not seen by day?—How many revolutions on its axis does the earth make in a year?—Why are we not sensible of the earth's daily motion

What proof have we of other motion not being perceptible?

Chapter. XXI.—*The Atmosphere.*

What is the atmosphere?—What does it possess?—Where is it most dense? And where more rare?

What does the whole mass of atmosphere contain?

To what purposes does it serve?—Of what appearances is it the cause
What do experiments on the air-pump prove?

Without an atmosphere how would the sky appear?—To what height does the atmosphere extend?—At what height does it cease to reflect the rays of light?—What results from the sun's rays falling upon the atmosphere before he rises? And after he sets?

When does twilight begin?—When does it end?

Chapter XXII.—*Refraction.*

When do the rays of light deviate from a rectilineal course?—From this cause what results?—What is the apparent elevation called?

Demonstrate this by fig. 1, plate XI.

What is the consequence of this refraction?—How much longer does the sun appear by this refraction?—Explain this by the figure.

How can you show the effects of refraction?—Have you not another way of demonstrating it?

Chapter XXIII.—*Parallax.*

What is the parallax of the sun or moon?

Which is called its *apparent*, and which its *true* place?

When is the parallax the *greatest*?—And what is that parallax called?

What is the sun's mean parallax? Why seldom made use of? And for what purpose?—Have the fixed stars any parallax?

Does the parallax of the sun or moon depress or elevate them? How must their true altitudes be obtained?—Illustrate this by fig. 2, plate XI.—Does distance cause the parallax to be greater or less?—Where has any object its *greatest* and where its *least* parallax? —When is the parallax nothing?—Explain this by the figure.

Chapter XXIV.—*Equation of Time.*

How much longer is the summer than the winter half year?—By what occasioned?—Of what is this inequality the cause?—What keeps true time?—And what apparent time?—What is the difference of these termed?

Equal time, how measured?—and apparent time, how?

Upon what does this difference depend?—What motion is the most equable in nature?—In what time is the earth's rotation completed? What is this space called? And why?

If the earth had only a diurnal motion, what would be the length of the day?

What is a solar or natural day?—By what is this difference occasioned?

Will the hands of a clock convey any idea of this?

How often are the ecliptic and zodiac coincident?—And when?—Why do they differ at other times?

Explain this by the globe.—Refer also to figure 2.—What do the marks on the ecliptic represent?—And what those on the equator?

In what quarters will the sun be *faster*, and in what *slower* than the clocks? And why?—Will not the elliptic form of the earth's orbit occasion a variation?

What, if the differences depended solely on the inclination of the earth's axis?—Refer to an Ephemeris for the times of the clock and dials coinciding, and say on what days.

If the earth's motions in its orbit were uniform, what would result?—What is the earth's daily course in winter, what in summer?—From this cause, what variations are there in the natural day? And why?—What then are the *combined* causes of the inequalities of time?

Chapter XXV.—*The Seasons.*

What is the inclination of the axis of the earth?—Explain this by the plate.—What is observed of the axis of the earth?

Illustrate the earth's parallelism.

What is the diameter of the earth's orbit?—To what does the axis of the earth always point, and how do you account for it?

Can you illustrate this by something familiar?

What proof is deduced from this?

How is the earth's course round the sun proved?

Can these observations be made in the day?

Upon what does the variety of the seasons depend?—What, if the axis of the earth were, as in the figure, perpendicular to the sun's rays

Why must the poles be excepted?

What would result from such a position?

On what does the proportion of heat materially depend?

Explain it by the figure.

Represent by figure 2, plate X, the position of the earth in our *summer season*

What is evident from the circle in the latitude of London ?—What is then the appearance at each pole?

What is observed of places in equal latitudes, the one north, the other south ?

Chapter XXVI.—*Seasons, continued.*

What is represented by fig. 2, plate XII. ?

How much nearer are we to the sun in December than in June ?—What is the sun's apparent diameter in winter ?—What in summer ?

What is the time we denominate our summer ?—How much longer than our winter half-year ?—What inference is consequent ?

Whence does the coldness of our winters arise ?—When are the *hottest* and when the *coldest* seasons ?

In June, what pole inclines to the sun ? And what results therefrom ?—In December what pole inclines to the sun ? And where is it then winter ?—In March and September what position has the axis ?—What length are the days and nights ?

In March, what is the real place of the earth ?—In what sign will the sun then appear ?—On the 21st of June, where is the sun vertical ?—Where in September ?—Where in December ?

What causes produce the increase and decrease of days and nights ?—To what parts is the sun vertical, from 20th March to 21st June ?—And from June to September ?

To what parts is the sun vertical from 23d September to 21st December ?—And from December to March ?—How often is the sun vertical to every part, between the tropics ?

Chapter XXVII.—*The Moon's Months, Phases.*

What kind of months are they ?—And what is the length of each ?—Whence arises the difference ?

Explain this by the figure.—Is the moon's orbit a circle, or an ellipsis ?

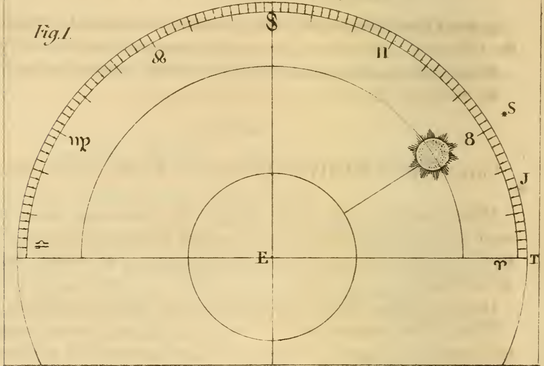
How much of the moon is at one time enlightened ?—Do we always see the whole enlightened side ?

Refer again to the figure.

What is the moon's position at change ?—What, at full moon ?—What, when changed ? And what is the moon then said to be in ?—What, when three-fourths are seen ?—What, when wholly enlightened ?

Procession of the Equinox

Fig. 1.



The * North * Pole * Star *

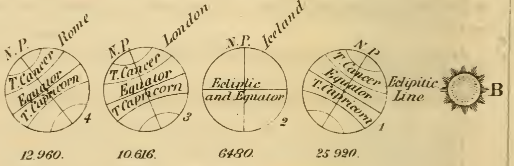
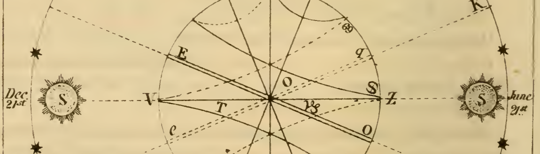


Fig. 3.



In what directions are the horns just after the change ?—What, after the full moon ?—Represent the moon's phases by a ball, or small globe.

What is the moon's *apparent* motion ?—What the *real* motion ?

By what may the moon's *real* motion be known ?

Chapter XXVIII.—*Eclipses—First, of the Moon.*

What does the term eclipse imply ?—By what is an eclipse of the moon occasioned ?—When must an eclipse of the moon happen ?—Refer to the plate.—What would result if the moon's orbit coincided with the ecliptic ?

How much does the orbit of the moon vary from the ecliptic ?

What is the *greatest* distance from the node, at which an eclipse of the moon can happen ?—When an eclipse happens full in the node, what is it called ?—What is the duration of an eclipse ?—Of what shape is the earth's shadow ?—Does not the moon's distance from the earth vary ?

How does the moon's being either nearer or more distant, affect the *length* of an eclipse ?

On which side of the moon does an eclipse begin, and on which side end ?

How may this be clearly conceived ?

How are eclipses calculated ?

Of what form is the earth's shadow ?—What does that demonstrate ?—How is the sun proved to be larger than the earth ?—If the two bodies were equal, of what shape would be the shadow ?—And if the earth were the larger body, of what shape would be the shadow ?

Eclipse of the Sun.

When does an eclipse of the sun happen ?—Explain it by the figure. Illustrate it by a suspended ball or globe.

If the *whole* of the sun be obscured, what is the eclipse termed ?—What, if only a *part ?*

What does the word *digit* mean ?

When, only, can the moon cover the sun's whole disc ?—Within how many degrees of the node can an eclipse happen ?—At all other *new moons*, how does she pass ?—And how at all other *full moons ?*—If an eclipse of the *moon* be *central*, what results ?—And what, if an eclipse of the *sun* be central ?—What are *annular* eclipses ?—By what occasioned ?—When only can an eclipse of the sun be *total ?*—How long may total darkness last?—How many *solar* eclipses in a year *must* there be?—What is the *least* number there *may* be?—What is the *least*, and what the *greatest* number of lunar eclipses?—How many eclipses may happen in a year?—In this case, how many of each?—What is the *mean* number of eclipses?—Why are there more solar than lunar eclipses?—And in what proportion?—Why, then, are more *lunar* than solar eclipses seen?

Chapter XXIX.—*Polar Day and Night.*

How are the long days and nights around the poles accounted for?—How, when the sun is on the equator?—How, when vertical to the tropic of *Cancer*?—What is the *extent* of the sun's rays?—What the length of each day and night?—And why?

What benefit have the polar regions from the *twilight*?—How long does the moon continue in their horizon?—Explain the reason.—What *third* benefit do they receive?—How does the moon's track vary from the sun's course?

When the sun is in the equator, in what point does he rise?—How, during the summer half-year?—How during the winter half-year?

Whence arises a small variation between the rising and setting?—Explain this by the globe.

Chapter XXX.—*Umbra and Penumbra.*

Explain the meaning of *Umbra* and *Penumbra* by the figure? Which parts will suffer a *total* eclipse, and which a *partial*?—How does the umbra fall in an annular eclipse?—And what will then be its appearance?—Which parts of the earth will have a *partial* eclipse?—And to what parts *no eclipse*.

How long can the annular appearance remain?—What is the moon's mean motion?—How many miles does it answer to?—What will be the *relative* velocity of the moon's shadow?—What affects the length of a solar eclipse?

Explain the different *eclipses* by the figure, in the 1st, 2d, and 3d positions.

What were the effects of a total eclipse of the sun according to Captain Stannyan?—What is Dr. Scheuchzer's account?—Relate Dr. Halley's description.

Chapter XXXI.—*Transits of Venus.*

Illustrate a *transit of Venus*, by the figure.—During which conjunction does the transit take place?—What is the principal use to which astronomers apply the transits of Venus?

To what other purposes are the transits applied?—Which take place the oftener, the transits of Mercury or Venus?—And which are of the greater utility?

What is meant by the occultation of the fixed stars?—By what methods are occultations ascertained?—What has Cassini remarked with respect to them?

What is meant by conjunction?—What by latitude?

What computations are needful to determine when an occultation will happen?

Will the appearance be different at different places upon the earth?—From what cause will the difference result?—To what extent may the moon's parallax affect the obscuration?

Chapter XXXII.—*The Harvest Moon.*

How much later does the moon often rise, one day than another?—Is there any difference in different latitudes?—What is her difference in rising about the time of harvest?

What is the difference to those who live in the latitude of London?

How does the autumnal full moon rise in considerable latitudes?—Why called the *Harvest Moon?*

By whom were these first observed?—And to what ascribed?—At what intervals of time does the moon rise about the equator?—When, at the polar circles?—How long does the moon shine within the polar circles without setting?—To what are these phenomena owing?—What is remarked of the signs *Pisces* and *Aries?*—What difference is there in the moon's rising when in these signs?—How do those signs of the ecliptic *set*, which rise with the smallest angles?

Illustrate this by the figure—demonstrate it by the globe.

What part of the ecliptic makes the *smallest* angles, in *northern* latitudes?—What, the greatest?—What angle is made by *Pisces* and *Aries* when rising?—What angle, when setting?—What is the moon's difference of rising when in Libra?

Demonstrate these phænomena on the globe.

Why is the moon at the full when in *Pisces* and *Aries* only in our autumnal months?—What are the two autumnal full moons called?

Chapter XXXIII.—*Harvest Moon continued.*

How often does it happen that the moon rises, for a week together, so nearly in point of time?

What time of the day do Pisces and Aries rise in *winter?*—And what is then the moon's age?—How do these signs rise in *spring?*—And what then the moon's age?—When do Pisces and Aries rise in *summer?*—What is then the moon's age?—Why is her rising then so unobserved?

In what time does the moon go through the ecliptic?—What is the time from change to change?—What results therefrom?

If the earth had no annual motion, how would every *new* and *full moon* fall?—And why?—How many degrees does the earth move during one lunation?—How does this affect the moon's conjunction, &c.?—If in any conjunction she were in at the first degree of Aries, where would her next conjunction be?—Why is the moon *twice in some one degree* every lunation?

How must the north and south poles appear to the inhabitants on the equator?—What angle does the ecliptic make to such?—And what results therefrom?—Why have they no Harvest Moon at the equator?—What effect has distance from the equator upon the rising of Pisces and Aries?

Illustrate this by the globe.

In what signs do the autumnal full moons happen to those in southern latitudes?—With what angles do Virgo and Libra rise?—What, with respect to harvest moons in southern latitudes?

What circumstance may cause some small difference in the time of the moon's rising or setting?—How much does the moon, at times, vary from the ecliptic?

To what part of the earth does the full moon not rise in summer?—To what part does she not set in winter?—Explain the cause of this satisfactorily.

Chapter XXXIV.—*Leap Year.*

What is the time we call a year?—What has been the usual division?—What were the ancient *Hebrew* months?—What the extent of their year?—Of how many days did the Athenian months consist? and by whom regulated?—How did Meton attempt to reconcile the difference? —How many months composed the year in the time of Romulus?—What addition was made to them by Numa Pompilius?—What was the length of the Egyptian year?

Who first attained to tolerable accuracy?—How did Julius Cæsar regulate the months?—How allow for the six odd hours?—What was every fourth year denominated?—And what is it now called?

What day did the Romans reckon twice?—And what was such intercalary day called?—What day do we *now* add in leap-year?

How is it ascertained what years are, and what are not leap-years?—Mention what year *will* and what *will not* be leap-years.—What is the length of the true solar year?—How much does 365 days 6 hours exceed the true solar year?—In how many years does it amount to a whole day?—How long did the Julian year continue in use?—Who reformed the calendar? And how?—How denominated?—In what year did we adopt the new style into our calendars?—And by what change in the days?—Why were the years 1800 and 1900 computed as common years?—And why, every four hundredth year afterwards?

What will result from this method of reckoning?

From what day was the beginning of the year changed?—How, for a time, did it affect the dates?

Chapter XXXV.—*The Tides*

Describe the fluctuations of the ocean.

What were the ancients' ideas of the tides?—Who made some successful advances?—And who clearly pointed out the cause?

What is the true cause of the flowing of the tides?

How is the moon proved to be the cause of the tides?

What would be the appearance, if there were no influence from the sun or moon?—What, if the earth and moon were without motion?—What proportion does the sun's attraction bear to that of the moon?—When the moon is at change, how many parts are raised?—If it be high water at A, fig. 4, plate XVI. what effect will it produce at C and D?

What is the attractive power of the sun and moon according to some authorities?

Explain the cause of low water at C and D.

Of what form will the waters partake at full and change?

Chapter XXXVI.—*The Tides, continued.*

In what proportion does the power of gravity diminish?—When there is a tide, as at A, fig. 4, plate XVI. what occasions a similar tide at B?—From what cause will two tides be produced each day?

How has it been otherwise explained?

How often does the tide ebb and flow in twenty-four hours?—What is the interval between the flux and reflux?—What is the daily variation as to the time of high water?

Give an example or two.

How are the tides affected at the *full* of the moon?—Explain this by fig. 6, plate XVI.

If there were no moon, how would the sun affect the tides?—When do the highest tides happen?—What are such tides called?—When the moon is in her quarters, what are the influences of the sun and moon?—What are such tides called?

Chapter XXXVII.—*The Tides, continued.*

Why are the tides higher at some seasons than at others?—How long is it, in open seas, after the moon passes the meridian, that the tides are at the highest?—And why?

Illustrate this by an impulse given to a moving ball—and by the time of the greatest heat of the day—and by the increasing heat in July and August.

Why do not the tides always answer to the moon's distance from the meridian?—When will the greatest *spring-tide* happen? And why?—Why do the tides rise higher in channels and rivers?

To what may the tides, in the mouths of rivers, be compared?

What retards the tides in shoals and channels?—And how much are they retarded?

How long does the tide take to come to London bridge?

Have lakes any tides?—What seas have but small elevations?—Give me the reason.

Are there tides in the air?

How long after the new and full moons do the greatest *spring-tides* happen?—And how long after the first and third quarters do the least *neap-tides* happen?—Are the tides unequal at places remote from the equator? Where is this inequality observed?—What has been remarked of the morning and the evening tides?

What results, when the moon's greatest elevation points to one side of the equator?

When and where is the inequality the greatest?--What is observed of the moon when she has declination?

Chapter XXXVIII.—*The Precession of the Equinox.*

What results from the earth's motion on its axis?—What arises from the attraction of the sun and moon?—If the sun sets out from any star, in what time will he return to it?—And why?

How do you prove that 20 minutes, 17⅓ seconds of time are equal to 50″ of a degree?—What is the sun's apparent annual motion?

When does the sun finish the *tropical* year?—And what does a tropical year contain?—When does he complete his sidereal year?—And what does it contain?—How much longer is the sidereal year than the solar or tropical?—And than the Julian or civil year?

Are the lengths of the sidereal and solar years the same as given by another author?

What is the sun's daily mean rate in a tropical year?—When will he arrive at the same equinox?—How long will the sun and equinoctial points be in falling back 30°?—What will be the apparent effect upon the fixed stars?

How do you prove that 50″ short in one year, are equal to a whole sign in 2160 years?—Explain it by fig. 1, plate XVII.

What results from the shifting of the equinoctial points?—What change has taken place since the infancy of astronomy?

How is the *motion* of the equinoctial points, or the precession of the equinoxes, found?—Who first observed this motion?—And by wha means?—With whom did Hipparchus compare his observations?

How many years is the equinox in shifting a whole degree?—How long for a whole sign?—What number of years completes the *grand celestial period?*

How much have the equinoctial points receded since the creation?

Chapters XXXIX and XL.—*Precession of the Equinox, continued.*

Explain the phænomena by fig. 3, plate XVII.

How do astronomers determine the obliquity of the ecliptic?

What did Eratosthenes, Ptolemy, Copernicus, and M. De la Lando find the obliquity to be?—From these observations what is deduced?

What is the secular diminution of the ecliptic at this time?

Give a full illustration of the precession of the equinox by the four small spheres, Plate XVII.—What does the sphere marked 1 exhibit?—What, the sphere 2?—What, the sphere 3?—What, the sphere 4?

Chapter XLI.—*Proportionate Magnitudes of the Planets.*

How is the proportion that one planet bears to another found? —Repeat the general law, *All spheres, &c.*

What is the cube of any number?—Demonstrate this by the cubes of 2 and 3.

Cube the numbers 893522, and 7920.—Divide the greater by the less.

To find the Planets' Distances from the Sun.

How is the earth's distance from the sun found?—What is its distance?—What other calculations can be made from it?—What general law did Kepler discover?—By whom was this law fully demonstrated?

What is meant by their *periodical times?*—Give instances of two or three.

How do we find the distance of Mercury from the sun?—Square 365.—Cube 95,000,000.—Square 88.—State the question, and perform the operation.

A

NEW TREATISE

ON THE

USE OF THE GLOBES;

DESIGNED FOR

THE INSTRUCTION OF YOUTH.

ABRIDGED FROM THE LARGER WORK OF

THOMAS KEITH.

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Problems performed with the Celestial Globe

A

NEW TREATISE

ON

THE USE OF THE GLOBES.

CHAPTER I.

Explanation of the lines on the Artificial Globes, including Geographical and Astronomical Definitions, with a few Geographical Theorems.

1 The Terrestrial Globe is an artificial representation of the earth. On this globe the four quarters of the world, the different empires, kingdoms and countries; the chief cities, seas, rivers, &c. are truly represented, according to their relative situation on the real globe of the earth. The diurnal motion of this globe is from west to east.

2. The Celestial Globe is an artificial representation of the heavens, on which the stars are laid down in their natural situations. The diurnal motion of this globe is from east to west, and represents the apparent diurnal motion of the sun, moon and stars. In using this globe, the student is supposed to be situated in the centre of it, and viewing the stars in the concave surface.

3. The Axis of the Earth is an imaginary line passing through the centre of it, upon which it is supposed to turn, and about which all the heavenly bodies appear to have a diurnal revolution. This line is represented by the wire which passes from north to south, through the middle of the artificial globe.

4. The Poles of the Earth are the two extremities of the axis, where it is supposed to cut the surface of the earth, one of which is called the north, or arctic pole; the other the south or antarctic pole. The celestial poles are two imaginary points in the heavens, exactly above the terrestrial poles.

5. The Brazen Meridian is the circle in which the artificial globe turns, and is divided into 360 equal parts, called degrees. In the upper semicircle of the brass meridian these degrees are numbered from 0 to 90, from the equator towards the poles, and are used for finding the latitudes of places. On the lower semicircle of the brass meridian they are numbered from 0 to 90, from the poles towards the equator, and are used in the elevation of the poles.

6. Great Circles divide the globe into two *equal* parts, as the equator, ecliptic, and the colures.

7. Small Circles divide the globe into two unequal parts, as the tropics, polar circles, parallels of latitude, &c.

8. Meridians, or Lines of Longitude, are *semicircles*, extending from the north to the south pole, and cutting the equator at right angles. Every place upon the globe is supposed to have a meridian passing through it, though there be only 24 drawn upon the terrestrial

globe; the deficiency is supplied by the brass meridian. When the sun comes to the meridian of any place (not within the polar circles,) it is noon or midday at that place.

9. The FIRST MERIDIAN is that from which geographers begin to count the longitudes of places. In English maps and globes the first meridian is a semicircle supposed to pass through London, or the royal observatory at Greenwich.

10. The EQUATOR is a great circle of the earth, equidistant from the poles, and divides the globe into two hemispheres, northern and southern. The latitudes of places are counted *from* the equator, northward and southward, and the longitude of places are reckoned *upon* it, eastward and westward.

The equator, when referred to the heavens, is called the *equinoctial;* because when the sun appears in it, the days and nights are equal all over the world, viz. 12 hours each. The declinations of the sun, stars and planets, are counted *from* the equinoctial northward and southward, and their right ascensions are reckoned *upon* it eastward round the celestial globe from 0 to 360 degrees.

11. The ECLIPTIC is a great circle in which the sun makes his apparent annual progress among the fixed stars; or it is the real path of the earth round the sun, and cuts the equinoctial in an angle of 23° 28′; the points of intersection are called the equinoctial points. The ecliptic is situated in the middle of the zodiac.

12. The ZODIAC, on the celestial globe, is a space which extends about eight degrees on each side of the

ecliptic, like a belt or girdle, within which the motion of all the planets* are performed.

13. SIGNS OF THE ZODIAC. The ecliptic and zodiac are divided into 12 equal parts, called signs, each containing 30 degrees. The sun makes his apparent annual progress through the ecliptic, at the rate of nearly a degree in a day. The names of the signs, and the days on which the sun enters them, are as follow:

SPRING SIGNS.

♈ *Aries*, the Ram, 21st of March.

♉ *Taurus*, the Bull, 19th of April.

♊ *Gemini*, the Twins, 20th of May.

SUMMER SIGNS.

♋ *Cancer*, the Crab, 21st of June.

♌ *Leo*, the Lion, 22d of July.

♍ *Virgo*, the Virgin, 22d of August.

These are called northern signs, being north of the equinoctial.

AUTUMNAL SIGNS.

♎ *Libra*, the Balance, 23d of September.

♏ *Scorpio*, the Scorpion, 23d of October.

♐ *Sagittarius*, the Archer, 22d of November.

WINTER SIGNS.

♑ *Capricornus*, the Goat, 21st December.

♒ *Aquarius*, the Water-bearer, 20th of January.

♓ *Pisces*, the Fishes, 19th February.

These are called southern signs.

The spring and winter signs are called *ascending* signs; because when the sun is in any of these, he

* Except the new discovered planets, or asteroids, *Ceres*, *Pallas*, and *Juno*.

is ascending towards our pole. The summer and autumn signs are called descending signs, because when the sun is in any of these, he is descending or receding from our pole.

14. The COLURES are two great circles passing through the poles of the world ; one of them passes through the equinoctial points, Aries and Libra ; the other through the solstitial points, Cancer and Capricorn ; hence they are called the equinoctial and solstitial colures. They divide the ecliptic into four equal parts, and mark the four seasons of the year.

15. DECLINATION of the sun, of a star, or planet, is its distance from the equinoctial, northward or southward. When the sun is in the equinoctial he has no declination, and enlightens half the globe from pole to pole. As he increases in north declination he gradually shines farther over the north pole, and leaves the south pole in darkness : in a similar manner, when he has south declination, he shines over the south pole, and leaves the north pole in darkness. The greatest declination the sun can have is 23° 28′ : the greatest declination a star can have is 90°, and that of a planet 30° 28′* north or south.

16. The TROPICS are two small circles, parallel to the equator (or equinoctial,) at the distance of 23° 28′ om it ; the northern is called the tropic of Cancer, the southern the tropic of Capricorn. The tropics are the limits of the torrid zone, northward and southward

17. The POLAR CIRCLES are two small circles, paral

* Except the planets, or asteroids, *Ceres, Pallas,* and *Juno,* which are nearly at the same distance from the sun ; the former, in April 1802, was out of the zodiac, its latitude being 15° 20′ N.

lel to the equator (or equinoctial,) at the distance of 66° 32′ from it, and 23° 28′ from the poles. The northern is called the *arctic*, the southern the *antarctic* circle.

18. Parallels of Latitude are small circles drawn through every ten degrees of latitude, on the terrestrial globe, parallel to the equator. Every place on the globe is supposed to have a parallel of latitude drawn through it, though there are generally only *sixteen* parallels of latitude drawn on the terrestrial globe.

19. The Hour Circle on the artificial globes is a small circle of brass, with an index or pointer fixed to the north pole; it is divided into 24 equal parts, corresponding to the hours of the day, and these are again subdivided into halves and quarters. The hour circle when placed *under* the brass meridian, is moveable round the axis of the globe, and the brass meridian, in this case, answers the purpose of an index.

20. The Horizon is a great circle which separates the visible half of the heavens from the invisible; the earth being considered as a point in the centre of the sphere of the fixed stars. Horizon, when applied to the earth, is either *sensible* or *rational.*

21. The Sensible, or visible horizon, is the circle which bounds our view, where the sky appears to touch the earth or sea.

22. The Rational, or true horizon, is an imaginary line passing through the centre of the earth parallel to the sensible horizon. It determines the rising and setting of the sun, stars, and planets.

23. The Wooden Horizon, circumscribing the ar-

tificial globe, represents the rational horizon on the real globe. This horizon is divided into several concentric circles, which on *Bardin's New British Globes* are arranged in the following order:

The First is marked amplitude, and is numbered from the east towards the north and south, from 0 to 90 degrees, and from the west towards the north and south in the same manner.

The Second is marked azimuth, and is numbered from the north point of the horizon towards the east and west, from 0 to 90 degrees: and from the south point of the horizon towards the east and west in the same manner.

The Third contains the 32 points of the compass, divided into half and quarter points. The degrees in each point are to be found in the amplitude circle.

The Fourth contains the twelve signs of the zodiac, with the figure and character of each sign.

The Fifth contains the degrees of the signs, each sign comprehending 30 degrees.

The Sixth contains the days of the month answering to each degree of the sun's place in the ecliptic.

The Seventh contains the equation of time, or difference of time shown by a well-regulated clock and a correct sun-dial. When the clock ought to be faster than the dial, the number of minutes, expressing the difference, is followed by the sign +; when the clock or watch ought to be slower, the number of minutes in the difference is followed by the sign —.

The Eighth contains the twelve calendar months.

24. The CARDINAL POINTS of the horizon are east, west, north, and south.

25. The CARDINAL POINTS in the heavens are the zenith, the nadir, and the points where the sun rises and sets.

26. The CARDINAL POINTS of the ecliptic are the equinoctial and solstitial points, which mark out the four seasons of the year; and the *Cardinal Signs* are ♈ Aries, ♋ Cancer, ♎ Libra, and ♑ Capricorn.

27. The ZENITH is a point in the heavens exactly over our heads, and is the elevated pole of our horizon

28. The NADIR is a point in the heavens exactly under our feet, being the depressed pole of our horizon, and the zenith, or elevated pole, of the horizon of our antipodes.

29. The POLE of any circle is a point on the surface of the globe, 90 degrees distant from every part of that circle of which it is the pole. Thus the poles of the earth are 90 degrees from every part of the equator; the poles of the ecliptic (on the celestial globe) are 90 degrees from every part of the ecliptic, and 23° 28′ from the poles of the equinoctial; consequently they are situated in the arctic and antarctic circles. Every circle on the globe, whether real or imaginary, has two poles diametrically opposite to each other.

30. The EQUINOCTIAL POINTS are Aries and Libra, where the ecliptic cuts the equinoctial. The point Aries is called the *vernal* equinox, and the point Libra the *autumnal* equinox. When the sun is in either of these points, the days and nights on every part of the globe are equal to each other.

31. The SOLSTITIAL POINTS are Cancer and Capri

corn. When the sun is in, or near, these points, the variation in his greatest altitude is scarcely perceptible for several days; because the ecliptic near these points is almost parallel to the equinoctial, and therefore the sun has nearly the same declination for several days. When the sun enters Cancer, it is the longest day to all the inhabitants on the north side of the equator, and the shortest day to those on the south side. When the sun enters Capricorn it is the shortest day to those who live in north latitude, and the longest day to those who live in south latitude.

32. An HEMISPHERE is half the surface of the globe; every *great circle* divides the globe into two hemispheres. The horizon divides the upper from the lower hemisphere in the heavens; the equator separates the northern from the southern on the earth; and the brass meridian, standing over any place on the terrestrial globe, divides the eastern from the western hemisphere.

33. The MARINER'S COMPASS is a representation of the horizon, and is used by seamen to direct and ascertain the course of their ships. It consists of a circular brass box, which contains a paper card, divided into 32 equal parts, and fixed on a magnetical needle that always turns *towards* the north. Each point of the compass contains 11° 15′ or 11¼ degrees, being the 32d part of 360 degrees.

34. The VARIATION OF THE COMPASS is the deviation of its points from the corresponding points in the heavens. When the north point of the compass is to the east of the true north point of the horizon, the va-

riation is east: if it be to the west, the variation is west.

The learner is to understand, that the compass does not always point *directly north*, but is subject to a small (irregular) annual variation. At present, 1830, in England, the needle points about 24½ degrees to the westward of the north.

The compass is used for setting the artificial globe north and south; but care must be taken to make a proper allowance for the variation.

35. LATITUDE OF A PLACE, on the terrestrial globe, is its distance from the equator in degrees, minutes, or geographical miles, &c. and is reckoned on the brass meridian, from the equator towards the north or south pole.

36. LATITUDE OF A STAR OR PLANET, on the celestial globe, is its distance from the ecliptic, northward or southward, counted towards the pole of the ecliptic, on the quadrant of altitude. The greatest latitude a star can have is 90 degrees, and the greatest latitude of a planet is nearly 8 degrees.* The sun being always in the ecliptic, has no latitude.

37. The QUADRANT OF ALTITUDE is a thin flexible piece of brass divided upwards from 0 to 90 degrees and downwards from 0 to 18 degrees, and when used is generally screwed to the brass meridian. The upper divisions are used to determine the distances of places on the earth, the distances of the celestial bodies, their altitudes, &c. and the lower divisions are applied to finding the beginning, end, and duration of twilight.

38. LONGITUDE OF A PLACE, on the terrestrial globe, is the distance of the meridian of that place from the first meridian, reckoned in degrees and parts of a de-

* The newly-discovered planets, or Asteroids, *Ceres* and *Pallas*, &c. do not appear to be confined within this limit.

gree on the equator. Longitude is either eastward or westward, according as the place is eastward or westward of the first meridian. The greatest longitude that a place can have is 180 degrees, or half the circumference of the globe.

39. LONGITUDE OF A STAR, OR PLANET, is reckoned on the ecliptic from the point Aries, eastward, round the celestial globe. The longitude of the sun is what is called the sun's place on the terrestrial globe.

40. ALMACANTARS, or parallels of latitude, are *imaginary* circles parallel to the horizon, and serve to show the height of the sun, moon, or stars. These circles are not drawn on the globe, but they may be described for any latitude by the quadrant of altitude.

41. PARALLELS OF CELESTIAL LATITUDE are small circles drawn on the celestial globe parallel to the ecliptic.

42. PARALLELS OF DECLINATION are small circles parallel to the equinoctial on the celestial globe, and are similar to the parallels of latitude on the terrestrial globe.

43. AZIMUTH, OR VERTICAL CIRCLES, are imaginary great circles passing through the zenith and the nadir, cutting the horizon at right angles. The altitudes of the heavenly bodies are measured on these circles, which circles may be represented by screwing the quadrant of altitude on the zenith of any place, and making the other end move along the wooden horizon of the globe.

44. The PRIME VERTICAL is that azimuth circle which passes through the east and west points of the

horizon, and is always at right angles to the brass meridian, which may be considered as another vertical circle passing through the north and south points of the horizon.

45. The Altitude of any object in the heavens is an arc of a vertical circle, contained between the centre of the object and the horizon. When the object is upon the meridian, this arc is called the meridian altitude.

46. The Zenith Distance of any celestial object is the arc of a vertical circle, contained between the centre of that object and the zenith; or it is what the altitude of the object wants of 90 degrees. When the object is on the meridian, this arc is called the meridian zenith distance.

57. The Polar Distance of any celestial object is an arc of a meridian, contained between the centre of that object and the pole of the equinoctial.

48. The Amplitude of any object in the heavens is an arc of the horizon, contained between the centre of the object when rising, or setting, and the east or west points of the horizon. Or, it is the distance which the sun or a star rises from the east, and sets from the west, and is used to find the variation of the compass at sea. When the sun has north declination, it rises to countries in north latitudes, to the north of the east, and sets to the north of the west; and when it has south declination, it rises to the south of the east, and sets to the south of the west. At the time of the equinoxes, when the sun has no declination, viz. on the 21st of March, and on the 23d of September, it rises exactly in the east, and sets exactly in the west.

49. The AZIMUTH of any object in the heavens is an arc of the horizon, contained between a vertical circle passing through the object, and the north or south points of the horizon. The azimuth of the sun, at any particular hour, is used at sea for finding the variation of the compass.

50. HOUR CIRCLES, or HORARY CIRCLES, are the same as the meridians. They are drawn through every 15 degrees* of the equator, each answering to an hour —consequently every degree of longitude answers to four minutes of time, every half degree to two minutes, and every quarter of a degree to *one* minute.

On the globes these circles are supplied by the brass meridian, the hour circle, and its index.

51. POSITIONS OF THE SPHERE are three: right, parallel, and oblique.

52. A RIGHT SPHERE is that position of the earth where the equinoctial passes through the zenith and the nadir, the poles being in the rational horizon. The inhabitants who have this position of the sphere, live at the equator: it is called a right sphere, because the parallels of latitude cut the horizon at right angles. In a right sphere the parallels of latitude are divided into two equal parts by the horizon, and the days and nights are of equal length.

53. A PARALLEL SPHERE is that position the earth has when the rational horizon coincides with the equator, the poles being in the zenith and nadir. The inhabitants who have this position of the sphere (if there

* On *Cary's* large Globes the meridians are drawn through every 10 degrees, as on a Map.

be any such inhabitants) live at the poles; it is called a parallel sphere, because all the parallels of latitude are parallel to the horizon. In a parallel sphere the sun appears above the horizon for six months together, and he is below the horizon for the same length of time.

54. An Oblique Sphere is that position the earth has when the rational horizon cuts the equator obliquely, and hence it derives its name. All inhabitants on the face of the earth (except those who live exactly at the poles or at the equator) have this position of the sphere. The days and nights are of unequal lengths, the parallels of latitude being divided into unequal parts by the rational horizon.

55. Climate is a part of the surface of the earth contained between two small circles parallel to the equator, and of such a breadth, that the longest day in the parallel nearest the pole, exceeds the longest day in the parallel of latitude nearest the equator, by half an hour, in the torrid and temperate zones, or by a month in the frigid zones; so that there are 24 climates between the equator and each polar circle, and six climates between each polar circle and its pole.

56. A Zone is a portion of the surface of the earth contained between two small circles parallel to the equator, and is similar to the term climate, for pointing out the situations of places on the earth, but less exact; as there are only *five* zones, which have been distinguished by particular names; whereas there are 60 climates.

57. The Torrid Zone extends from the tropic of

Cancer to the tropic of Capricorn, and is 46° 56′ broad. This zone was thought by the ancients to be uninhabited, because it is continually exposed to the direct rays of the sun ; and such parts of the torrid zone as were known to them were sandy deserts, as the middle of Africa, Arabia, &c.; and these sandy deserts extend beyond the left bank of the Indus, toward Agimere.

58. The Two Temperate Zones. The north temperate zone extends from the tropic of Cancer to the arctic circle ; and the south temperate zone from the tropic of Capricorn to the antarctic circle. These zones are each 43° 4′ broad, and were called temperate by the ancients, because meeting the sun's rays obliquely, they enjoy a moderate degree of heat.

59. The Two Frigid Zones. The north frigid zone, or rather segment of the sphere, is bounded by the arctic circle. The north pole, which is 23° 28′ from the arctic circle, is situated in the centre of this zone. The south frigid zone is bounded by the antarctic circle, distant 23° 28′ from the south pole, which is situated in the centre of this zone.

60. Amphiscii are the inhabitants of the torrid zone ; so called, because their shadows fall north or south at different times of the year ; the sun being sometimes to the south of them at noon, and at other times to the north. When the sun is vertical, or in the zenith, which happens twice in the year, the inhabitants have no shadow, and are then called Ascii, or shadowless.

61. Heteroscii is a name given to the inhabitants of the temperate zones, because their shadows at noon fall only one way. Thus, the shadow of an inhabitant

of the north temperate zone always falls to the north at noon, because the sun is then due south; and the shadow of an inhabitant of the south temperate zone falls towards the south at noon, because the sun is due north at that time.

62. Periscii are those people who inhabit the frigid zones, so called, because their shadows, during a revolution of the earth on its axis, are directed towards every point of the compass. In the frigid zones the sun does not set during several revolutions of the earth on its axis.

63. Antœci are those who live in the same degree of longitude, and in equal degrees of latitude, but the one in north and the other in south latitude. They have noon at the same time, but contrary seasons of the year; consequently, the length of the days to the one, is equal to the length of the nights to the other. Those who live at the equator can have no Antœci.

64. Periœci are those who live in the same latitude, but in opposite longitudes; when it is noon with the one, it is midnight with the other; they have the same length of days, and the same seasons of the year. The inhabitants of the poles can have no Periœci.

65. Antipodes are those inhabitants of the earth who live diametrically opposite to each other, and consequently walk feet to feet; their latitudes, longitudes, seasons of the year, days and nights, are all contrary to each other.

66. The Right Ascension of the sun, or of a star, is that degree of the equinoctial which rises with the

sun, or star, in a right sphere, and is reckoned from the equinoctial point Aries eastward round the globe.

67. Oblique Ascension of the sun or of a star, is that degree of the equinoctial which rises with the sun or star, in an oblique sphere, and is likewise counted from the point Aries eastward round the globe.

68. Oblique Descension of the sun, or of a star, is that degree of the equinoctial which sets with the sun or star in an oblique sphere.

69. The Ascensional or Descensional Difference is the difference between the right and oblique ascension, or the difference between the right and oblique descension, and, with respect to the sun, it is the time he rises before 6 in the spring and summer, or sets before 6 in the autumn and winter.

70. The Crepusculum, or Twilight, is that faint light which we perceive before the sun rises, and after he sets. It is produced by the rays of light being refracted in their passage through the earth's atmosphere, and reflected from the different particles thereof. The twilight is supposed to end in the evening when the sun is 18 degrees below the horizon, or when stars of the sixth magnitude (the smallest that are visible to the naked eye) begin to appear; and the twilight is said to begin in the morning, or it is *day-break*, when the sun is again within 18 degrees of the horizon. The twilight is the shortest at the equator, and longest at the poles; here the sun is near two months before he retreats 18 degrees below the horizon, or to the point where his rays are first admitted into the atmosphere;

and he is only two months more before he arrives at the same parallel of latitude.

71. ANGLE OF POSITION between two places on the terrestrial globe, is an angle at the zenith of one of the places, formed by the meridian of that place, and a vertical circle passing through the other place, being measured on the horizon from the elevated pole towards the vertical circle.

THE ANGLE OR POSITION OF A STAR, is an angle formed by two great circles intersecting each other in the place of the star, the one passing through the pole of the equinoctial, the other through the pole of the ecliptic.

72. BAYER'S CHARACTERS. John Bayer, of Augsburg in Swabia, published in 1603 an excellent work, entitled *Uranometria*, being a complete atlas of all the constellations, with the useful invention of denoting the stars in every constellation by the letters of the Greek and Roman Alphabets; setting the first Greek letter α to the principal star in each constellation, β to the second in magnitude, γ to the third, and so on, and when the Greek alphabet was finished, he began *a*, *b*, *c*, &c. of the Roman. This useful method of describing the stars has been adopted by all succeeding astronomers, who have farther enlarged it by adding the numbers, 1, 2, 3, &c. in the same regular succession, when any constellation contains more stars than can be marked by the two alphabets. The figures are, however, sometimes placed above the Greek letter, especially where double stars occur; for though many stars may appear single to the naked eye, yet when viewed through a telescope of considerable magnifying power they appear double, triple, &c. Thus, in Dr. Zach's Tabulæ

Motuum Solis, we meet with *f* Tauri, β Tauri, γ Tauri, δ^1 Tauri, δ^2 Tauri, &c.

As the Greek letters so frequently occur in catalogues of the stars and on the celestial globes, the Greek alphabet is here introduced for the use of those who are unacquainted with the letters. The capitals are seldom used in the catalogues of stars, but are here given for the sake of regularity.

		Name.	*Sound.*			*Name.*	*Sound.*
Α	α	Alpha	a	Ν	ν	Nu	n
Β	β ϐ	Beta	b	Ξ	ξ	Xi	x
Γ	γ ͳ	Gamma	g	Ο	ο	Omicron	o *short*
Δ	δ	Delta	d	Π	π ϖ	Pi	p
Ε	ε	Epsilon	e *short*	Ρ	ϱ ρ	Rho	r
Ζ	ζ ζ	Zeta	z	Σ	σ ς ϛ	Sigma	s
Η	η	Eta	e *long*	Τ	τ ٦	Tau	t
Θ	ϑ θ	Theta	th	Υ	υ	Upsilon	u
Ι	ι	Iota	i	Φ	φ	Phi	ph
Κ	κ	Kappa	k	Χ	χ	Chi	ch
Λ	λ	Lambda	l	Ψ	ψ	Psi	ps
Μ	μ	Mu	m	Ω	ω	Omega	o *long*

73. Diurnal Arc is the arc described by the sun, moon, or stars, from their rising to their setting. The sun's semi-diurnal arc is the arc described in half the length of the day.

74. Nocturnal Arc is the arc described by the sun, moon, or stars, from their setting to their rising.

75. Aberration is an apparent motion of the celestial bodies, occasioned by the earth's annual motion in its orbit, combined with the progressive motion of light.

CHAPTER II.

PROBLEMS PERFORMED WITH THE TERRESTRIAL GLOBE.

Problem I.

To find the latitude of any given place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles; the degree above the place is the latitude. If the place be on the north side of the equator, the latitude is north; if it be on the south side the latitude is south.

On small globes the latitude of a place cannot be found nearer than to about a quarter of a degree. Each degree of the brass meridian on the largest globes is generally divided into three equal parts, each part containing twenty geographical miles; on such globes the latitude may be found to 10′.

Examples.—What is the latitude of Edinburgh?

Answer.—56° north.

2 Required the latitudes of the following places:

Amsterdam	Florence	Philadelphia
Archangel	Gibraltar	Quebec
Barcelona	Hamburgh	Rio Janeiro
Batavia	Ispahan	Stockholm
Bencoolen	Lausanne	Turin
Berlin	Lisbon	Vienna
Cadiz	Madras	Warsaw
Canton	Madrid	Washington
Dantzic	Naples	Wilna
Drontheim	Paris	York

3 Find all the places on the globe which have no latitude.

4. What is the greatest latitude a place can have?

Problem II.

To find all those places which have the same latitude as any given place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and observe its latitude; turn the globe round, and all places passing under the observed latitude are those required.

All places in the same latitude have the same length of day and night, and the same seasons of the year, though from local circumstances, they may not have the same atmospherical temperature.

Examples. 1. What places have the same, or nearly the same latitude as Madrid?

Answer. Minorca, Naples, Constantinople, Samarcand, Philadelphia, Pekin, &c.

2. What inhabitants of the earth have the same length of days as the inhabitants of Edinburgh?

3. What places have nearly the same latitude as London?

4. What inhabitants of the earth have the same seasons of the year as those of Ispahan?

5. Find all the places of the earth which have the longest day the same length as at Port Royal in Jamaica.

Problem III.

To find the Longitude of any place.

Rule. Bring the given place to the brass meridian, the number of degrees on the equator, reckoning from the meridian passing through London to the brass meridian is the longitude. If the place lie to the right hand of the meridian passing through London, the longitude is east; if to the left hand, the longitude is west.

On *Adams'* and *Cary's* globes there are two rows of figures above the equator. When the place lies to the right hand of the meridian of London, the longitudes must be counted on the upper line; when it lies to the left hand it must be counted on the lower line. *Bardin's* New British Globes have also two rows of figures above the equator, but the lower line is always used in reckoning the longitude.

EXAMPLES. 1. What is the longitude of Petersburg?

Answer. 30¼° east.

2. What is the longitude of Philadelphia?

Answer 75¼° west.

3. Required the longitudes of the following places

Aberdeen	Civita Vecchia	Lisbon
Alexandria	Constantinople	Madras
Barbadoes	Copenhagen	Masulipatam
Bombay	Drontheim	Mecca
Botany Bay	Ephesus	Nankin
Canton	Gibraltar	Palermo
Carlscrona	Leghorn	Pondicherry
Cayenne	Liverpool	Queda.

4. What is the greatest longitude a place can have?

PROBLEM IV.

To find all those places that have the same longitude as a given place.

RULE. Bring the given place to the brass meridian then all places under the same edge of the meridian from pole to pole have the same longitude.

All people situated under the same meridian from 66° 28 north latitude to 66° 28′ south latitude, have noon at the same time; or, if it be one, two, three, or any number of hours before or after noon with one particular place, it will be the same hour with every other place situated under the same meridian.

Examples. 1. What places have the same, or nearly the same longitude as Stockholm?

Answer. Dantzic, Presburg, Tarento, the Cape of Good Hope, &c.

2. What places have the same longitude as Alexandria?

3. When it is ten o'clock in the evening at London, what inhabitants of the earth have the same hour?

4. What inhabitants of the earth have midnight when the inhabitants of Jamaica have midnight?

5. What places of the earth have the same longitude as the following places?

London	Quebec	The Sandwich islands
Pekin	Dublin	Pelew islands.

Problem V.

To find the latitude and longitude of any place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles; the degree above the place is the latitude, and the degree on the equator, cut by the brass meridian, is the longitude.

This problem is only an exercise of the *first* and *third.*

Examples. 1. What are the latitude and longitude of Petersburg?

Answer. Latitude 60° N. longitude 30¼° E.

2. Required the latitudes and longitudes of the following places:

Acapulco	Cusco	Lima
Aleppo	Copenhagen	Lizard
Algiers	Durazzo	Lubec
Archangel	Elsinore	Malacca
Belfast	Flushing	Manilla
Bergen	Cape Guardafui	Medina
Buenos Ayres	Hamburgh	Mexico
Calcutta	Jeddo	Mocha
Candy	Jaffa	Moscow
Corinth	Ivica	Oporto.

Problem VI.

To find any place on the globe having the latitude and longitude of that place given.

Rule. Find the longitude of the given place on the equator, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; then under the given latitude, on the brass meridian, you will find the place required.

Examples. 1. What place has $151\frac{1}{2}°$ east longitude, and 34° south latitude?

Answer. Botany Bay.

2. What places have the following latitudes and longitudes?

Latitudes.	Longitude.	Latitude.	Longitude.
50° 6′ N.	5° 54′ W.	19° 26′ N.	100° 6′ W
48 12 N.	16 16 E.	59 56 N.	30 19 E.
55 58 N.	3 12 W.	0 13 S.	77 55 W
52 22 N.	4 51 E.	46 55 N.	69 53 W
31 13 N.	29 55 E.	59 21 N.	18 4 E

64° 34′ N	38° 58′ E.	8° 32′ N.	81° 11′ E.
34 29 S.	18 23 E.	5 9 S.	119 49 E.
3 49 S.	102 10 E.	22 54 S.	42 44 W
34 35 S.	58 31 W.	36 5 N.	5 22 W
32 25 N.	52 50 E.	32 38 N.	17 6 W.

Problem VII.

To find the difference of latitude between any two places.

Rule. Bring one of the places to that half of the brass meridian which is numbered from the equator towards the poles, and mark the degree above it; then bring the other place to the meridian, and the number of degrees between it and the above mark will be the difference of latitude.

Or, Find the latitudes of both the places (by Prob. 1.) then, if the latitudes be both north or both south, subtract the less latitude from the greater, and the remainder will be the difference of latitude; but, if the latitudes be one north and the other south, add them together, and their sum will be the difference of latitude.

Examples. 1. What is the difference of latitude between Philadelphia and Petersburgh?

Answer. 20 degrees.

2. What is the difference of latitude between Madrid and Buenos Ayres?

Answer. 75 degrees.

3. Required the difference of latitude between the following places?

London and Rome
Delhi and Cape Comorin
Alexandria and the Cape of Good Hope

Vera Cruz and Cape Horn	Pekin and Lima
Mexico and Botany Bay	St. Salvador and Surinam
Astracan and Bombay	Washington and Quebec
St. Helena and Manilla	Porto Bello and the Straits of Magellan
Copenhagen and Toulon	Trinidad I. and Trincomalé
Brest and Inverness	Bencoolen and Calcutta.
Cadiz and Sierra Leone	

4. What two places on the globe have the greatest difference of latitude?

Problem VIII.

To find the difference of longitude between any two places.

Rule. Bring one of the given places to the brass meridan, and mark its longitude on the equator; then bring the other place to the brass meridian, and the number of degrees between its longitude and the above mark, counted on the equator, the nearest way round the globe, will show the difference of longitude.

Or, Find the longitudes of both the places (by Prob. III.) then, if the longitudes be both east or both west, subtract the less longitude from the greater, and the remainder will be the difference of longitude: but, if the longitude be one east and the other west, add them together, and their sum will be the difference of longitude.

When this sum exceeds 180 degrees, take it from 360, and the remainder will be the difference of longitude.

Examples. 1. What is the difference of longitude between Barbadoes and Cape Verd?

Answer. 43° 42′.

2. What is the difference of longitude between Buenos Ayres and the Cape of Good Hope?

Answer. 76° 54′

3. What is the difference of longitude between Botany Bay and O'why'ee?

Answer. 52° 45′, or 52¾ degrees.

4. Required the difference of longitude between the following places:

Vera Cruz and Canton
Bergen and Bombay
Columbo and Mexico
Juan Fernandes I. and Manilla
Pelew I. and Ispahan
Boston in Amer. and Berlin
Constantinople and Batavia
Bermudas I. and I. of Rhodes
Port Patrick and Berne
Mount Heckla and Mount Vesuvius
Mount Ætna and Teneriffe
North Cape and Gibraltar.

5. What is the greatest difference of longitude comprehended between two places?

Problem IX.

To find the distance between any two places.

Rule. The shortest distance between any two places on the earth, is an arc of a great circle contained between the two places. Therefore, lay the graduated edge of the quadrant of altitude over the two places, so that the division marked 0 may be on one of the places the degrees on the quadrant comprehended between the two places will give their distance; and if these degrees be multiplied by 60, the product will give the distance in geographical miles; or multiply the degrees by $69\frac{1}{2}$, and the product will give the distance in English miles.

Or, Take the distance between the two places with a pair of compasses, and apply that distance to the equa tor, which will show how many degrees it contains.

If the distance between the two places should exceed the length of the quadrant, stretch a piece of thread over the two places, and mark their distance; the extent of thread between these marks, applied to the equator, from the meridian of London, will show the number of degrees between the two places.

Examples. 1. What is the nearest distance between the Lizard and the island of Bermudas?

$45\frac{3}{4}$ distance in degrees.	$45\frac{3}{4}$ distance in degrees.
60	$69\frac{1}{2}$
2700	$22\frac{7}{8}$
30	405
15	270
2745 geographical miles.	$34\frac{1}{2}$
	$17\frac{1}{4}$
	$3176\frac{5}{8}$ English miles.

2. What is the nearest distance between the island of Bermudas and St. Helena?

$73\frac{1}{2}$ distance in degrees.	$73\frac{1}{2}$ distance in degrees.
60	$69\frac{1}{2}$
4380	$36\frac{3}{4}$
30	657
4410 geographical miles.	438
	$34\frac{1}{2}$
	$5108\frac{1}{4}$ English miles.

3. What is the nearest distance between London and Botany Bay.

154 distance in degrees.	154 distance in degrees
60	$69\frac{1}{2}$
9240 geographical miles.	77
	1386
	924
	10703 English miles.

4. What is the direct distance between London and Jamaica, in geographical and English miles?

5. What is the extent of Europe in English miles, from Cape Matopan in the Morea, to the North Cape in Lapland?

6. What is the extent of Africa from Cape Verd to Cape Guardafui?

7. What is the extent of south America from Cape Blanco in the west to Cape St. Roque in the east?

8. Suppose the track of a ship to Madras be from the Lizard to St. Anthony, one of the Cape Verd islands, thence to St. Helena, thence to the Cape of Good Hope, thence to the east of the Mauritius, thence a little to the south-east of Ceylon, and thence to Madras; how many English miles is the Land's End from Madras?

Problem X.

A place being given on the globe, to find all places, which are situated at the same distance from it as any other given place.

Rule. Lay the graduated edge of the quadrant of altitude over the two places, so that the division marked 0 may be on one of the places, then observe what degree of the quadrant stands over the other place; move the quadrant entirely round, keeping the division marked 0 in its first situation, and all places which pass under the same degree which was observed to stand over the other place, will be those sought.

Or, Place one foot of a pair of compasses in one of the given places, and extend the other foot to the other given place: a circle described from the first place as a centre, with this extent, will pass through all the places sought.

If the distance between the two given places should exceed the length of the quadrant, or the extent of a pair of compasses, stretch a piece of thread over the two places, as in the preceding problem.

Examples. 1. It is required to find all the places on the globe which are situated at the same distance from London as Warsaw is?

Answer. Koningsburg, Buda, Posega, Alicant, &c.

2. What places are at the same distance from London as Petersburg is?

3. What places are at the same distance from London as Constantinople is?

4. What places are at the same distance from Rome as Madrid is?

Problem XI.

Given the latitude of a place and its distance from a given place, to find that place whereof the latitude is given.

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by 69½ for English miles, or 60 for geographical miles, then put that part of the graduated edge of the quadrant of altitude which is marked 0 upon the given place, and move the other end eastward or westward (according as the required place lies to the east or west of the given place,) till the degrees of distance cut the given parallel of latitude : under the point of intersection you will find the place sought.

Or, Having reduced the miles into degrees, take the same number of degrees from the equator with a pair of compasses, and with one foot of the compass in the given place, as a centre, and his extent of degrees, describe a circle on the globe ; turn the globe till this circle falls under the given latitude on the brass meridian, and you will find the place required.

Examples. 1. A place in latitude 60° N. is 1320½ English miles from London, and it is situated in E. longitude ; required the place?

Answer. Divide 1320½ miles by 69½ miles, or which is the same thing, 2641 half-miles by 139 half-miles, the quotient will give 19 degrees ; hence the required place is Petersburgh.

2. A place in latitude 32½° N. is 1350 geographical miles from London, and it is situated in W. longitude; required the place?

Answer. Divide 1350 by 60, the quotient is 22° 30′, or 22½ degrees ; hence the required place is the west point of the island of Madeira.

3. What place in E. longitude and 41° N. latitude, is 1529 English miles from London?

4. What place in W. longitude and 13° N. latitude, is 3660 geographical miles from London?

Problem XII.

Given the longitude of a place and its distance from a given place, to find that place whereof the longitude is given.

Rule. If the distance be given in English or geographical miles, turn them into degrees by dividing by

69½ for English miles, or 60 for geographical miles, then put that part of the graduated edge of the quadrant of altitude which is marked 0 upon the given place, and move the other end northward or southward (according as the required place lies to the north or south of the given place,) till the degrees of distance cut the given longitude: under the point of intersection you will find the place sought.

Or, Having reduced the miles into degrees, take the same number of degrees from the equator with a pair of compasses, and with one foot of the compasses in the given place, as a centre, and this extent of degrees, describe a circle on the globe; bring the given longitude to the brass meridian, and you will find the place, upon the circle, under the brass meridian.

Examples. 1. A place in north latitude, and in 60 degrees west longitude, is 4239½ English miles from London; required the place?

Answer. Divide 4239½ miles by 69½ miles, or, which is the same thing, 8479 half-miles by 139 half-miles, the quotient will give 61 degrees; hence the required place is the island of Barbadoes.

2. A place in north latitude, and in 75¼ degrees west longitude, is 3120 geographical miles from London; what place is it?

3. A place in 31¼ degrees east longitude, and situated southward of London, is 2224 English miles from it; required the place?

4. A place in 29 degrees east longitude, and situated southward of London, is 1529 English miles from it, required the place?

Problem XIII.

To find how many miles make a deg. of longitude in any given parallel of latitude.

Rule. Lay the quadrant of altitude parallel to the equator, between any two meridians in the given latitude, which differ in longitude 15 degrees; the number of degrees intercepted between them multiplied by 4, will give the length of a degree in geographical miles. The geographical miles may be brought into English miles by multiplying by 116, and cutting off two figures from the right-hand of the product.

Or, Take the distance between two meridians, which differ in longitude 15 degrees in the given parallel of latitude, with a pair of compasses; apply this distance to the equator, and observe how many degrees it makes: with which proceed as above.

Since the quadrant of altitude will measure no arc truly but that of a great circle; and a pair of compasses will only measure the chord of an arc, not the arc itself; it follows that the preceding rule cannot be mathematically true, though sufficiently correct for practical purposes. When great exactness is required, recourse must be had to calculation.

The above rule is founded on a supposition that the number of degrees contained between any two meridians, reckoned on the equator is to the number of degrees contained between the same meridians, on any parallel of latitude, as the number of geographical miles contained in one degree of the equator, is to the number of geographical miles contained in one degree on the given parallel of latitude. Thus in the latitude of London, two places which differ 15 degrees in longitude are $9\frac{1}{4}$ degrees distant by the rule. Hence,

15° : $9\frac{1}{4}$: : 60m. : 37m.; or 15° : 60m. : : $9\frac{1}{4}$: 37m.; but 15 is to 60 as 1 is to 4, therefore, 1 : 4 : : $9\frac{1}{4}$: 37 geographical miles contained in one degree. Now, any number of geographical miles may be brought into English miles by multiplying by $69\frac{1}{2}$ and dividing by 60; or by multiplying by 1.16; for 60 : $69\frac{1}{2}$: : 1.16 *nearly*.

EXAMPLES. 1. How many geographical and English miles make a degree in the latitude of Pekin?

Answer. The latitude of Pekin is 40° north: the distance between two meridians in that latitude (which differ in longitude 15 degrees) 11½ degrees. Now, 11½ degrees multiplied by 4, produces 46 geographical miles for the length of a degree of longitude, in the latitude of Pekin; and if 46 be multiplied by 116, the product will be 5336; cut off the two right hand-hand figures, and the length of a degree in English miles will be 53. OR, by the rule of three, 15° : 69½m. : : 11½° · 53 miles.

2. How many miles make a degree in the parallels of latitude wherein the following places are situated?

Surinam	Washington	Spitzbergen
Barbadoes	Quebec	Cape Verd
Havana	Skalholt	Alexandria
Bermudas I.	North Cape	Paris.

PROBLEM XIV

To find the bearing of one place from another.

RULE. If both the places be situated on the same parallel of latitude, their bearing is either east or west from each other; if they be situated on the same meridian, they bear north and south from each other; if they be situated on the same rhumb-line, that rhumb-line is their bearing: if they be not situated on the same rhumb-line, lay the quadrant of altitude over the two places, and that rhumb-line which is the nearest of being parallel to the quadrant will be their bearing.

OR, If the globe have no rhumb-lines drawn on it, make a small mariner's compass (*such as in Plate* I. *fig*. 4.) and apply the centre of it to any given place, so that the north and south points may coincide with some meridian; the other points will show the bearings of all the circumjacent places, to the distance of upwards of a thousand miles, if the centrical place be not far distant from the equator.

Examples. 1. Which way must a ship steer from the Lizard to the island of Bermudas?

Answer. W. S. W.

2. Which way must a ship steer from the Lizard to the island of Madeira?

Answer. S. S. W.

3. Required the bearing between London and the following places?

Amsterdam	Copenhagen	Petersburg
Athens	Dublin	Prague
Bergen	Edinburgh	Rome
Berlin	Lisbon	Stockholm
Berne	Madrid	Vienna
Brussels	Naples	Warsaw.
Buda	Paris	

Problem XV.

To find the angle of position between two places.

Rule. Elevate the north or south pole, according as the latitude is north or south, so many degrees above the horizon as are equal to the latitude of one of the given places; bring that place to the brass meridian, and screw the quadrant of altitude upon the degree over it; next move the quadrant till its graduated edge falls upon the other place; then the number of degrees on the wooden horizon, between the graduated edge of the quadrant and the brass meridian, reckoning towards the elevated pole, is the angle of position between the two places.

EXAMPLES. 1. What is the angle of position between London and Prague?

Answer. 90 degrees from the north towards the east: the quadrant of altitude will fall upon the east point of the horizon, and pass over or near the following places, viz. Rotterdam, Frankfort, Cracow, Ockzakov, Caffa, south part of the Caspian Sea, Guzerat in India, Madras, and part of the island of Ceylon. Hence all these places have the same angle of position from London.

2. What is the angle of position between London and Port Royal in Jamaica?

Answer. 90 degrees from the north towards the west; the quadrant of altitude will fall upon the west point of the horizon.

3. What is the angle of position between Philadelphia and Madrid?

Answer. 65 degrees from the north towards the east; the quadrant of altitude will fall between the E. N. E. and N. E. by E. points of the horizon.

4. Required the angles of position between London and the following places?

Amsterdam	Copenhagen	Rome
Berlin	Cairo	Stockholm
Berne	Lisbon	Petersburg
Constantinople	Madras	Quebec

PROBLEM XVI.

To find the Antœci, Periœci, and Antipodes to the inhabitants of any place.

RULE. Place the two poles of the globe in the horizon, and bring the given place to the eastern part of the horizon; then, if the given place be in north latitude, observe how many degrees it is to the northward of the east point of the horizon; the same number of degrees to the southward of the east point will show the Antœci; an equal number of degrees, counted from the west point of the horizon towards the north, will show the Periœci; and the same number of degrees, counted towards the south of the west, will point out the Antipodes. If the place be in south latitude, the same rule will serve by reading south for north, and the contrary.

Or thus:

For the Antœci. Bring the given place to the brass meridian and observe its latitude; then in the opposite hemisphere, under the same degree of latitude, you will find the Antœci.

For the Periœci. Bring the given place to the brass meridian, and set the index of the hour circle to 12, turn the globe half round, or till the index points to the other 12; then under the latitude of the given place you will find the Periœci.

For the Antipodes. Bring the given place to the brass meridian, and set the index of the hour circle to 12, turn the globe half round, or till the index points to the other 12; then under the same degree of latitude with the given place, but in the opposite hemisphere, you will find the Antipodes.

Examples. 1. Required the Antœci, Periœci, and Antipodes, to the inhabitants of the island of Bermudas?

Answer. Their Antœci are situated in Paraguay, a little N. W. of Buenos Ayres; their Periœci in China, N W of Nankin; and their Antipodes in the S. W. part of New Holland.

2. Required the Antœci, Periœci, and Antipodes to the inhabitants of the Cape of Good Hope?

3. Captain Cook, in one of his voyages, was in 50 degrees south latitude and 180 degrees of longitude; in what part of Europe were his Antipodes?

4. Required the Antœci to the inhabitants of the Falkland islands?

5. Required the Periœci to the inhabitants of the Philippine islands?

6. What inhabitants of the earth are Antipodes to those of Buenos Ayres?

To find at what rate per hour *the inhabitants of any given place are carried, from west to east, by the revolution of the earth on its axis.*

Rule. Find how many miles make a degree of longitude in the latitude of the given place (by Problem XIII.) which multiply by 15 for the answer.

Or, look for the latitude of the given place in the table, Problem IX., against which you will find the number of miles contained in one degree; multiply these miles by 15, and reject two figures from the right hand of the product; the result will be the answer.

Examples. 1. At what rate *per* hour are the inhabitants of Madrid carried from west to east by the revolution of the earth on its axis?

Answer. The latitude of Madrid is about 40° N. where a degree of longitude measures 46 geographical, or 53 English miles (see Example 1. Prob. XIII.) Now 46 multiplied by 15 produces 690; and 53 multiplied by 15 produces 795; hence the inhabitants of Madrid are carried 690 geographical, or 795 English miles *per hour.*

By the Table. Against the latitude 40 you will find 45·96 geographical miles, and 52·85 English miles: Hence,
44·95 × 15 = 689·40 and 52·85 × 15 = 792·75, by rejecting the two right-hand figures from each product, the result will be 689 geographical miles, and 792 English miles, agreeing nearly with the above.

2. At what rate *per* hour are the inhabitants of the following places carried from west to east by the revolution of the earth on its axis?

Skalholt	Philadelphia	Cape of Good Hope
Spitzbergen	Cairo	Calcutta
Petersburgh	Barbadoes	Delhi
London	Quito	Batavia.

Problem XVIII.

A particular place, and the hour of the day at that place being given, to find what hour it is at any other place.

Rule. Bring the place at which the time is given to the brass meridian, and set the index of the hour circle to 12; turn the globe till the other place comes to the meridian, and the hours passed over by the index will be the difference of time between the two places. If the place where the hour is sought lie to the east of that wherein the time is given, count the difference of time forward from the given hour; if it lie to the west, reckon the difference of time backward.

Or, without the hour circle.

Find the difference of longitude between the two places (by Problem VIII.) and turn it into time by allowing 15 degrees to an hour, or four minutes of time to one degree. The difference of longitude in time will be the difference of time between the two places, with which proceed as above. Degrees of longitude may be turned into time by multiplying by 4; observing that minutes or miles of longitude, when multiplied by 4, produce seconds of time; and degrees of longitude, when multiplied by 4, produce minutes of time.

Some globes have two rows of figures on the hour circle, others but one: this difference frequently occasions confusion; and the manner in which authors in general direct a learner to solve those problems wherein the hour circle is used, serves only to increase that confusion. In this, and in all the succeeding problems, great care has been taken to render the rules general for any hour circle whatsoever.

EXAMPLES. 1. When it is ten o'clock in the morning at London, what hour is it at Petersburgh?

Answer. The difference of time is two hours; and, as Petersburg is eastward of London, this difference must be counted forward, so that it is 12 o'clock at noon at Petersburg.

OR, the difference of longitude between Petersburgh and London is 30° 25′, which multiplied by 4 produces two hours 1 min. 40 sec. the difference of time shown by the clocks of London and Petersburgh. hence as Petersburgh lies to the east of London; when it is ten o'clock in the morning at London, it is one minute and 40 seconds past 12 at Petersburgh.

2. When it is two o'clock in the afternoon at Alexandria in Egypt, what hour is it at Philadelphia?

Answer. The difference of time is seven hours; and because Philadelphia lies to the westward of Alexandria, this difference must be reckoned backward, so that it is seven o'clock in the morning at Philaphia.

Or,	The longitude of Alexandria is	30°	16′ E.
	The longitude of Philadelphia is	75	11 W.
	Difference of longitude	105	27
			4

Difference of longitude in time 7 h. 1 m. 48 sec.; the clocks at Philadelphia are slower than those of Alexandria; hence when it is two o'clock in the afternoon at Alexandria, it is 58 m. 12 sec. past six in the morning at Philadelphia.

3. When it is noon at London, what hour is it at Calcutta?

4. When it is ten o'clock in the morning at London, what hour is it at Washington?

5. When it is nine o'clock in the morning at Jamaica, what o'clock is it at Madras?

6. My watch was well regulated at London, and when I arrived at Madras, which was after a five months' voyage, it was four hours and fifty minutes slower than the clocks there. Had it gained or lost during the voyage? and how much?

Problem XIX.

A particular place and the hour of the day being given, to find all places on the globe where it is then noon, or any other given hour.

Rule. Bring the given place to the brass meridian, and set the index of the hour circle to 12; then, as the difference of time between the given and required places is always known by the problem, if the hour at the required places be earlier than the hour at the given place, turn the globe eastward till the index has passed over as many hours as are equal to the given difference of time; but, if the hour at the required places be later than the hour at the given place, turn the globe westward till the index has passed over as many hours as are equal to the given difference of time; and, in each case, all the places required will be found under the brass meridian.

Or, without the hour circle.

Reduce the difference of time between the given place and the required places into minutes: these minutes, divided by 4, will give degrees of longitude; if there be a remainder after dividing by 4, multiply it by 60, and divide the product by four, the quotient will be minutes or miles of longitude. The difference of longitude between the given place and the required places being thus determined, if the hour at the required places be earlier than the hour at the given place, the required places lie so many degrees to the westward of the given place as are equal to the difference of longitude; if the hour at the required places be later than the hour at the given place, the required places lie so many degrees to the eastward of the given place as are equal to the difference of longitude.

EXAMPLES. 1. When it is noon at London, at what places is it half past eight o'clock in the morning?

Answer. The difference of time between London, the given place, and the required places, is 3½ hours, and the time at the required places is *earlier* than that at London; therefore the required places lie 3½ hours westward of London; consequently, by bringing London to the brass meridian, setting the index to 12, and turning the globe eastward till the index has passed over 3½ hours, all the required places will be under the brass meridian, as the eastern coast of Newfoundland, Cayenne, part of Paraguay, &c.

OR, The difference of time between London, the given place, and the required places, is 3 hours 30 min.

```
 3 h. 30 m.
 60
 ------
4)120 m.
 ------
 52°—2
     60
 ------
  4)120
 ------
   30 m.
```

The difference of longitude between the given place and the required places is 52° 30′ The hour at the required places being earlier than that at the given place, they lie 52° 30′ westward of the given place. Hence, all places situated in 52° 30′ west longitude from London, are the places sought, and will be found to be Cayenne, &c. as above.

2. When it is two o'clock in the afternoon at London, at what places is it ½ past five in the afternoon?

Answer. Here the difference of time between London, the given place, and the required places, is 3½ hours; but the time at the required places is *later* than at London. The operation will be the same as in example 1, only the globe must be turned 3½ hours towards the west, because the required places will be in east longitude, or eastward of the given place. The places sought are the Caspian Sea, western part of Nova Zembla, the island of Socotra, eastern part of Madagascar, &c.

3. When it is ¾ past four in the afternoon at Paris, where is it noon?

4. When it is ¾ past seven in the morning at Ispahan, where is it noon?

5. When it is noon at Madras, where it is ½ past six o'clock in the morning?

6. At sea in latitude 40° north, when it was ten o'clock in the morning by the time-piece which shows the hour at London, it was exactly 9 o'clock in the morning at the ship, by a correct celestial observation. In what part of the ocean was the ship?

7. When it is noon at London, what inhabitants of the earth have midnight?

8. When it is ten o'clock in the morning at London, where is it ten o'clock in the evening?

Problem XX.

To find the sun's longitude (commonly called the sun's place in the ecliptic) and his declination.

Rule. Look for the given day in the circle of months on the horizon, against which, in the circle of signs, are the sign and degree in which the sun is for that day. Find the same sign and degree in the ecliptic on the surface of the globe; bring the degree of the ecliptic, thus found, to that part of the brass meridian which is numbered from the equator towards the poles; its distance from the equator reckoned on the brass meridian, is the sun's declination.

This problem may be performed by the celestial globe, using the same rule.

Or, by the analemma.

Bring the analemma to that part of the brass meridian which is numbered from the equator towards the poles, and the degree on the brass meridian, exactly above the day of the month, is the sun's declination. Turn the globe till a point of the ecliptic, corresponding to the day of the month, passes under the degree of the sun's declination, that point will be the sun's longitude or place for the given day. If the sun's declination be *north*, and increasing, the sun's longitude will be somewhere between Aries and Cancer. If the declination be decreasing, the longitude will be between Cancer and Libra. If the sun's declination be *south* and increasing, the sun's longitude will be between Libra and Capricorn; if the declination be decreasing the longitude will be between Capricorn and Aries.

The sun's longitude and declination are given in the *second* page of every month, in the *Nautical Almanac* for every day in that month: they are likewise given in *White's Ephemeris*, for every day in the year.

Examples. 1. What is the sun's longitude and declination on the 15th of April?

Answer. The sun's place is 26° in ♈, declination 10° N.

2. Required the sun's place and declination for the following days?

January 21.	May 18	September 9.
February 7.	June 11	October 16.
March 16.	July 11	November 17.
April 8.	August 1.	December 1.

Problem XXI.

To place the globe in the same situation WITH RESPECT TO THE SUN, *as our earth is at the* EQUINOXES, *at the* SUMMER SOLSTICE, *and at the* WINTER SOLSTICE, *and thereby to show the comparative lengths of the longest and shortest days.**

1. For the Exuinoxes. Place the two poles of the globe in the horizon: for at this time the sun has no declination, being in the equinoctial in the heavens, which is an imaginary line standing vertically over the equator on the earth. Now, if we suppose the sun to be fixed, at a considerable distance from the globe, vertically over that point of the brass meridian which is marked 0, it is evident that the wooden horizon will be the boundary of light and darkness on the globe, and that the upper hemisphere will be enlightened from pole to pole.

* In this problem, as in all others where the pole is elevated to the sun's declination, the sun is supposed to be fixed, and the earth to move on its axis from west to east. The author of this work has a little brass ball made to represent the sun; this ball is fixed upon a strong wire, and when used, slides out of a socket like an acromatic telescope. The socket is made to screw to the brass meridian (of any globe) over the sun's declination, and the little brass ball representing the sun, stands over the declination, at a considerable distance from the globe.

Meridians, or lines of longitude, being generally drawn on the globe through every 15 degrees of the equator, the sun will *apparently* pass from one meridian to another in an hour. If you bring the point Aries on the equator to the eastern part of the horizon, the point Libra will be in the western part thereof; and the sun will appear to be setting to the inhabitants of London * and to all places under the same meridian. let the globe be now turned gently on its axis towards the east, the sun will appear to move towards the west, and, as the different places successively enter the dark hemisphere, the sun will appear to be setting in the west. Continue the motion of the globe eastward, till London comes to the western edge of the horizon; the moment it emerges above the horizon, the sun will appear to be rising in the east. If the motion of the globe on its axis be continued eastward, the sun will appear to rise higher and higher, and to move towards the west; when London comes to the brass meridian, the sun will appear at its greatest height; and after London has passed the brass meridian, he will continue his apparent motion westward, and gradually diminish in altitude till London comes to the eastern part of the horizon, when he will again be setting. During this revolution of the earth on its axis, every place on its surface has been twelve hours in the dark hemisphere, and twelve hours in the enlightened hemisphere; consequently the days and nights are equal all over the world; for all the parallels of latitude are divided into

* The meridian of London is here supposed to pass through the equinoctial point Aries, as on the best modern globes.

two equal parts by the horizon, and in every degree of latitude there are six meridians between the eastern part of the horizon and the brass meridian; each of these meridians answers to one hour, hence half the length of the day is six hours, and the whole length twelve hours.

If any place be brought to the brass meridian, the number of degrees between that place and the horizon (reckoned the nearest way) will be the sun's meridian altitude. Thus, if London be brought to the meridian the sun will then appear exactly south, and its altitude will be 38½ degrees; the sun's meridian altitude at Philadelphia will be 50 degrees; his meridian altitude at Quito 90 degrees; and here, as in every place on the equator, as the globe turns on its axis, the sun will be vertical. At the Cape of Good Hope the sun will appear due north at noon, and his altitude will be 55½ degrees.

2. For the Summer Solstice.—The summer solstice, to the inhabitants of north latitude, happens on the 21st of June, when the sun enters Cancer, at which time his declination is 23° 28′ north. Elevate the north pole 23½ degrees above the northern point of the horizon, bring the sign of Cancer in the ecliptic to the brass meridian, and over that degree of the brass meridian under which this sign stands, let the sun be supposed to be fixed at a considerable distance from the globe.

While the globe remains in this position, it will be seen that the equator is exactly divided into two equal parts, the equinoctial point Aries being in the western part of the horizon, and the opposite point Libra in the eastern part, and between the horizon and the brass meridian (counting on the equator) there are six meridians, each fifteen degrees, or an hour apart; consequently the day at the equator is twelve hours long. From the equator northward as far as the arctic circle, the *diurnal arcs* will exceed the *nocturnal arcs;* that is, more than one half of any of the parallels of latitude will be above the horizon, and of course less than one half will be below, so that the days are longer than the nights. All the parallels of latitude within the Arctic circle will be wholly above the horizon, consequently those inhabitants will have no night. From the equator southward, as far as the Antarctic circle, the *nocturnal arcs* will exceed the *diurnal arcs ;* that is, more than one half of any one of the parallels of latitude will be below the horizon, and consequently less than one half will be above. All the parallels of latitude within the Antarctic circle, will be wholly below the horizon, and the inhabitants, if any, will have twilight or dark night.

From a little attention to the parallels of latitude, while the globe remains in this position, it will easily be seen that the arcs of those parallels which are above the horizon north of the equator, are exactly of the same length as those below the horizon, south of the equator; consequently, when the inhabitants of north latitude have the longest day, those in south latitude have the longest night. It will likewise appear, that the arcs of those parallels which are above the horizon, south of the equator, are exactly of the same length as those below the horizon, north of the equator; therefore, when the inhabitants who are situated south of the equator have the shortest day, those who live north of the equator have the shortest night.

By counting the number of meridians, (supposing them to be drawn through every fifteen degrees of the equator) between the horizon and the brass meridian, on any parallel of latitude, half the length of the day will be determined in that latitude, the double of which is the length of the day.

1. In the parallel of 20 degrees north latitude, there are six meridians and two thirds more, hence the longest day is 13 hours and 20 minutes; and in the parallel of 20 degrees south latitude there are five meridians and one third, hence the shortest day in that latitude is ten hours and forty minutes.

2. In the parallel of 30 degrees north latitude, there are seven meridians between the horizon and the brass meridian, hence the longest day is 14 hours; and in the same degree of south latitude there are only five meridians, hence the shortest day in that latitude is ten hours.

3. In the parallel of 50 degrees north latitude there are eight meridians between the horizon and the brass meridian; the longest day is therefore sixteen hours: and in the same degree of south latitude there are only four meridians; hence the shortest day is eight hours.

4. In the parallel of 60 degrees north latitude, there are $9\frac{1}{4}$ meridians from the horizon to the brass meridian, hence the longest day is $18\frac{1}{2}$ hours; and in the same degree of south latitude, there are only $2\frac{3}{4}$ me-

ridians, the length of the shortest day is therefore 5½ hours.

By turning the globe gently round on its axis from west to east, we shall readily perceive that the sun will be vertical to all the inhabitants under the tropic of Cancer, as the places successively pass the brass meridian.

If any place be brought to the brass meridian, the number of degrees between that place and the horizon (reckoning the nearest way) will show the sun's meridian altitude. Thus, at London, the sun's meridian altitude will be found to be about 62 degrees; at Petersburgh 54½ degrees, at Madrid 73 degrees, &c. To the inhabitants of these places the sun appears due south at noon. At Madras the sun's meridian altitude will be 79½ degrees, at the Cape of Good Hope 32 degrees, at Cape Horn 10½ degrees, &c. The sun will appear due north to the inhabitants of these places at noon. If the southern extremity of Spitzbergen, in latitude 76½ north, be brought to that part of the brass meridian which is numbered from the equator towards the poles, the sun's meridian altitude will be 37 degrees, which is its greatest altitude; and if the globe be turned eastwards twelve hours, or till Spitzbergen comes to that part of the brass meridian which is numbered from the pole towards the equator, the sun's altitude will be ten degrees, which is its least altitude for the day given in the problem. It was shown, in the foregoing part of the problem, that, when the sun is vertically over the equator in the vernal equinox, the north pole begins to be enlightened; consequently the farther the sun apparently proceeds in its course northward, the more day-light will be diffused over the north polar regions, and the sun will appear gradually to increase in altitude at the north pole, till the 21st of June, when his greatest height is 23½ degrees; he will then gradually diminish in height till the 23d of September, the time of the autumnal equinox, when he will leave the north pole, and proceed towards the south; consequently the sun has been visible at the north pole for six months.

3. For the Winter Solstice.—The winter solstice, to the inhabitants of north latitude, happens on the 21st of December, when the sun enters Capricorn, at which time his declination is 23° 28′ south. Elevate the south pole 23½ degrees above the southern point of the horizon, bring the sign of Capricorn in the ecliptic to the brass meridian, and over that degree of the brass meridian under which this sign stands, let the sun be supposed to be fixed at a considerable distance from the globe.

Here, as at the summer solstice, the days at the equator will be twelve hours long, but the equinoctial point Aries will be in the eastern part of the horizon, and Libra in the western. From the equator southward, as far as the Antarctic circle, the *diurnal arcs* will exceed the *nocturnal arcs*. All the parallels of latitude within the Antarctic circle will be wholly above the horizon. From the equator northward, the *nocturnal arcs* will exceed the *diurnal arcs*. All the parallels of latitude within the Arctic circle will be wholly below the horizon. The inhabitants south of the equatc will now have their longest day, while those on the north of the equator will have their shortest day.

As the globe turns on its axis from west to east, the sun will be vertical successively to all the inhabitants under the tropic of Capricorn. By bringing any place to the brass meridian, and finding the sun's meridian altitude (as in the foregoing part of the problem,) the greatest altitudes will be in south latitude, and the least in the north; contrary to what they were before. Thus, at London, the sun's greatest altitude will be only 15 degrees, instead of 62; and its greatest altitude at Cape Horn will now be 57½ degrees, instead of 10½, as at the summer solstice; hence it appears, that the difference between the sun's greatest and least meridian altitude at any place in the temperate zone, is equal to the breadth of the torrid zone, viz. 47 degrees, or more correctly 46° 56′. On the 23d of September, when the sun enters Libra, that is, at the time of the autumnal equinox, the south pole begins to be enlightened, and, as the sun's declination increases southward, he will shine farther over the south pole, and gradually increase in altitude at the pole; for, at all times, his altitude at either pole is equal to his declination. On the 21st of December, the sun will have the greatest south declination, after which his altitude at the south pole will gradually diminish as his declination diminishes; and on the 21st of March, when the sun's declination is nothing, he will appear to skim along the horizon at the south pole, and likewise at the north pole; the sun has therefore been visible at the south pole for six months.

Problem XXII.

To place the globe in the same situation, WITH RESPECT TO THE POLAR STAR *in the heavens, as our earth is to the inhabitants of the equator, &c. viz. to illustrate the three positions of the sphere*, RIGHT, PARALLEL *and* OBLIQUE, *so as to show the comparative length of the longest and shortest days.*

1. For the Right Sphere. The inhabitants who live upon the equator have a right sphere, and the north polar star appears always in (or very near) the horizon. Place the two poles of the globe in the horizon, then the north pole will correspond with the north polar star, and all the heavenly bodies will *appear* to revolve round the earth from east to west, in circles parallel to the equinoctial, according to their different declinations: one half of the starry heavens will be constantly above the horizon, and the other half below, so that the stars will be visible for twelve hours, and invisible for the same space of time; and, in the course of 6 months, an inhabitant upon the equator may see all the stars in the heavens. The ecliptic being drawn on the terrestrial globe, young students are often led to imagine that the sun apparently moves daily round the earth in the same oblique manner. To correct this false idea, we must suppose the ecliptic to be transferred to the heavens, where it properly points out the sun's apparent annual path amongst the fixed stars. The sun's diurnal path is either over the equator, as at the time of the equinoxes, or in lines nearly parallel to the equator; this may be correctly illustrated by fastening one end of a

piece of packthread upon the point Aries on the equator, and winding the packthread round the globe towards the right hand, so that one fold may touch another, till you come to the tropic of Cancer: thus you will have a correct view of the sun's apparent diurnal path from the vernal equinox to the summer solstice; for, after a diurnal revolution, the sun does not come to the same point of the parallel whence it departed, but, according as it approaches to or recedes from the tropic, is a little above or below that point. When the sun is in the equinoctial, he will be vertical to all the inhabitants upon the equator, and his apparent diurnal path will be over that line: when the sun has ten degrees of north declination, his apparent diurnal path will be from east to west nearly along that parallel. When the sun has arrived at the tropic of Cancer, his diurnal path in the heavens will be along that line, and he will be vertical to all the inhabitants on the earth in latitude 23° 28′ north. The inhabitants upon the equator will always have twelve hours day and twelve hours night, notwithstanding the variation of the sun's declination from north to south, or from south to north; because the parallel of latitude which the sun apparently describes for any day, will always be cut into two equal parts by the horizon. The greatest meridian altitude of the sun will be 90°, and the least 66° 32′. During one half of the year, an inhabitant on the equator will see the sun full north at noon, and during the other half it will be full south.

2. For the Parallel Sphere. The inhabitants, (if any) who live at the north pole have a parallel sphere and the north polar star in the heavens appears exactly

(or very nearly) over their heads. Elevate the north pole ninety degrees above the horizon, then the equator will coincide with the horizon, and all the parallels of latitude will be parallel thereto. In the summer half-year, that is, from the vernal to the autumnal equinox, the sun will appear above the horizon, consequently the stars and planets will be invisible during that period. When the sun enters Aries, on the 21st March, he will be seen by the inhabitants of the north pole (if there be any inhabitants) to skim just along the edge of the horizon: and as he increases in declination, he will increase in altitude, forming a kind of spiral course, as before described, by wrapping a thread round the globe. The sun's altitude at any particular hour is always equal to his declination. The greatest altitude the sun can have is 23° 28′, at which time he has arrived at the tropic of Cancer; after which he will gradually decrease in altitude as his declination decreases. When the sun arrives at the sign Libra, he will again appear to skim along the edge of the horizon, after which he will totally disappear, having been above the horizon for six months. Though the inhabitants at the north pole will lose sight of the sun a short time after the autumnal equinox, yet the twilight will continue for nearly two months; for the sun will not be 18° below the horizon till he enters the 20th of Scorpio, as may be seen by the globe.

After the sun has descended 18° below the horizon, all the stars in the northern hemisphere will become visible, and appear to have a diurnal revolution round the earth from east to west, as the sun appeared to have when he was above the horizon. These stars will never set; and the planets, when they are in any of the northern signs, will be visible. The inhabitants under the north polar star have the moon constantly above their horizon during fourteen revolutions of the earth on its axis; and at every full moon which happens from the 23d of September to the 21st of March, the moon is in some of the northern signs, and consequently visible at the north pole; for the sun being below the horizon at that time, the moon must be above the horizon, because she is always in that sign which is diametrically opposite to the sun at the time of full moon.

When the sun is at his greatest depression below the horizon, being then in Capricorn, the moon is at her First Quarter in Aries: Full in Cancer; and at her Third Quarter in Libra: and as the beginning of Aries is the rising point of the ecliptic, Cancer the highest, and Libra the setting point, the moon rises at her First Quarter in Aries, is most elevated above the horizon, and Full in Cancer, and sets at the beginning of Libra in her Third Quarter; having been visible for fourteen revolutions of the earth on its axis, viz. during the moon's passage from Aries to Libra. Thus the north pole is supplied one half of the winter time with constant moonlight in the sun's absence, and the inhabitants only lose sight of the moon from her Third to her First Quarter, while she gives but little light, and can be of little or no service to them.

3. For the Oblique Sphere. Whenever the terrestrial globe is placed in a proper situation with res-

pect to the fixed stars, the pole must be elevated as many degrees above the horizon as are equal to the latitude of the given place, and the north pole of the globe must point to the north polar star in the heavens; for in sailing, or travelling from the equator northward, the north polar star appears to rise higher and higher. On the equator it will appear in the horizon; in 10 degrees of north latitude it will be ten degrees above the horizon; in twenty degrees of north latitude it will be twenty degrees above the horizon; and so on, always increasing in altitude as the latitude increases. Every inhabitant of the earth, except those who live upon the equator, or exactly under the north polar star, has an oblique sphere, viz. the equator cuts the horizon obliquely. By elevating and depressing the poles, in several problems, a young student is sometimes led to imagine that the earth's axis moves northward and southward just as the pole is raised or depressed: this is a mistake, the earth's axis has no such motion.* In travelling from the equator northward, our horizon varies; thus, when we are on the equator, the northern point of our horizon is in a line with the north polar star; when we have travelled to ten degrees north latitude, the north point of our horizon is ten degrees below the pole, and so on: now, the wooden horizon on the terrestrial globe is immovable, otherwise it ought to be elevated or depressed, and not the pole; but whether we elevate the pole ten degrees above the horizon, or depress the north point of the horizon ten degrees

* The earth's axis has a kind of librating motion, called the *nutation* but this cannot be represented by elevating or depressing the pole.

below the pole, the appearance will be exactly the same.

The latitude of London is about $51\frac{1}{2}°$ north; if London be brought to the brass meridian, and the north pole be elevated $51\frac{1}{2}°$ above the north point of the wooden horizon, then the wooden horizon will be the true horizon of London; and, if the artificial globe be placed exactly north and south by a mariner's compass, or by a meridian line, it will have *exactly* the position which the *real globe* has. Now, if we imagine lines to be drawn through every degree within the torrid zone, parallel to the equator, they will nearly represent the sun's diurnal path on any given day. By comparing these diurnal paths with each other, they will be found to increase in length from the equator northward, and to decrease in length from the equator southward; consequently, when the sun is going north from the equator, the days are increasing in length to us; and when going from the equator, the days are decreasing. The sun's meridian altitude, for any day, may be found by counting the number of degrees from the parallel in which the sun is on that day, towards the horizon, upon the brass meridian; thus, when the sun is in that parallel of latitude which is ten degrees north of the equator, his meridian altitude will be $48\frac{1}{2}°$. Though the wooden horizon be the true horizon of the given place, yet it does not separate the enlightened hemisphere of the globe from the dark hemisphere, when the pole is thus elevated. For instance, when the sun is in Aries, and London at the meridian, all the places on the globe above the horizon beyond those meridians which pass through the east and west points thereof, reckoning towards the north, are in darkness, notwithstanding they are above the horizon: and all places below the horizon, between those same meridians and the southern point of the horizon, have day-light, notwithstanding they are below the horizon of London.

Problem XXIII.

The month and day of the month being given, to find all places of the earth where the sun is vertical on that day; those places where the sun does not set, and those places where he does not rise on the given day.

Rule. Find the sun's declination (by Problem XX.) for the given day, and mark it on the brass meridian; turn the globe round on its axis from west to east, and all the places which pass under this mark will have the sun vertical on that day.

Secondly. Elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination: turn the globe on its axis from west to east; then, to those places which do not descend below the horizon, in that frigid zone near the elevated pole, the sun does not set on the given day: and to those places which do not ascend above the horizon, in that frigid zone adjoining to the depressed pole, the sun does not rise on the given day.

Or, by the analemma.

Bring the analemma to that part of the brass meridian which is numbered from the equator towards the poles, the degree directly above the day of the month on the brass meridian, is the sun's declination. Elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination; turn the globe on its axis from west to east, then to those places which pass under the sun's declination, on the brass meridian the sun will be vertical; to those places (in that frigid zone near the elevated pole) which do not go below the horizon, the sun does not set; and to those places (in that frigid zone near the depressed pole) which do not come above the horizon, the sun does not rise on the given day.

Examples. 1. Find all places of the earth where the sun is vertical on the 11th of May, those places in the north frigid zone where the sun does not set, and those places in the south frigid zone where he does not rise.

Answer. The sun is vertical at St. Anthony, one of the Cape Verd islands, the Virgin islands, south of St. Domingo, Jamaica, Golconda, &c. All the places within eighteen degrees of the north pole will have constant day; and those (if any) within eighteen degrees of the south pole will have constant night.

2. Whether does the sun shine over the north or south pole on the 27th of October, to what places will he be vertical at noon, what inhabitants of the earth will have the sun below their horizon during several revolutions, and to what part of the globe will the sun never set on that day?

3. Find all the places of the earth where the inhabitants have no shadow when the sun is on their meridian on the first of June.

4. What inhabitants of the earth have their shadows directed to every point of the compass during a revolution of the earth on its axis on the 15th of July?

5. How far does the sun shine over the south pole on the 14th of November, what places in the north frigid zone are in perpetual darkness, and to what places is the sun vertical?

6. Find all places of the earth where the moon will be vertical on the 3d of June 1827.

Problem XXIV.

A place being given in the torrid zone, to find those two days of the year on which the sun will be vertical at that place.

Rule. Bring the given place to that part of the brass meridian which is numbered from the equator towards the poles, and mark its latitude; turn the globe on its axis, and observe what two points of the ecliptic pass under that latitude: seek those points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months stand the days required

Or, by the analemma.

Find the latitude of the given place (by Problem I) and mark it on the brass meridian; bring the analemma to the brass meridian, upon which, exactly under the latitude, will be found the two days required.

Examples. 1. On what two days of the year will the sun be vertical at Madras?

Answer On the 25th of April and on the 18th of August.

2 On what two days of the year is the sun vertical at the following places?

O'why'hee	St. Helena	Sierra Leone
Friendly Isles	Rio Janeiro	Vera Cruz
Straits of Alass	Quito	Manilla
Penang	Barbadoes	Tinian Isle
Trincomalé	Porto Bello	Pelew Islands.

Problem XXV.

The month and the day of the month being given (at any place not in the frigid zones,) to find what other day of the year is of the same length.

Rule. Find the sun's place in the ecliptic for the given day, (by Problem XX.) bring it to the brass meridian, and observe the degree above it; turn the globe on its axis till some other point of the ecliptic falls under the same degree of the meridian: find this point of the ecliptic on the horizon, and directly against it you will find the day of the month required.

This Problem may be performed by the celestial globe in the same manner.

Or, by the analemma.

Look for the given day of the month on the analemma, and adjoining to it you will find the required day of the month.

Or, without a globe.

Any two days of the year which are of the same length, will be an equal number of days from the longest or shortest day. Hence, whatever number of days the given day is before the longest or shortest day, just so many days will the required day be after the longest or shortest day, *et contra*.

EXAMPLES. 1. What day of the year is of the same length as the 25th of April?

Answer. The 18th of August.

2. What day of the year is of the same length as the 25th of May?

3. If the sun rise at four o'clock in the morning at London on the 17th of July, on what other day of the year will it rise at the same hour?

4. If the sun set at seven o'clock in the evening at London on the 24th of August, on what other day of the year will it set at the same hour?

5. If the sun's meridian altitude be 90° at Trincomalé, in the island of Ceylon, on the 12th of April, on what other day of the year will the meridian altitude be the same?

6. If the sun's meridian altitude at London on the 25th of April be 51° 35′, on what other day of the year will the meridian altitude be the same?

7. If the sun be vertical at any place on the 15th of April, how many days will elapse before he is vertical a second time at that place?

8. If the sun be vertical at any place on the 20th of August, how many days will elapse before he is vertical a second time at that place?

Problem XXVI.

The month, day, and hour of the day being given, to find where the sun is vertical at that instant.

Rule. Find the sun's declination (by Problem XX.) and mark it on the brass meridian; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; but, if the given time be past noon, turn the globe *eastward* as many hours as the time is past noon; the place exactly under the degree of the sun's declination will be that sought.

Examples. 1. When it is forty minutes past six o'clock in the morning at London on the 25th of April, where is the sun vertical?

Answer. Here the given time is five hours twenty minutes before noon; hence the globe must be turned towards the *west* till the index has passed over five hours twenty minutes, and under the sun's declination on the brass meridian you will find Madras, the place required.

2. When it is four o'clock in the afternoon at London on the 18th of August, where is the sun vertical?

Answer. Here the given time is four hours past noon; hence the globe must be turned towards the *east*, till the index has passed over four hours, then, under the sun's declination, you will find Barbadoes, the place required.

3. When it is three o'clock in the afternoon at London on the 4th of January, where is the sun vertical?

4. When it is three o'clock in the morning at London on the 11th of April, where is the sun vertical?

5. When it is thirty-seven minutes past one o'clock

in the afternoon at the Cape of Good Hope on the 5th of February, where is the sun vertical?

6. When it is eleven minutes past one o'clock in the afternoon at London on the 29th of April, where is the sun vertical?

7. When it is twenty minutes past five o'clock in the afternoon at Philadelphia on the 18th of May, where is the sun vertical?

8. When it is nine o'clock in the morning at Calcutta on the 11th of April, where is the sun vertical?

Problem XXVII.

The month, day, and hour of the day at any place being given, to find all those places of the earth where the sun is rising, those places where the sun is setting, those places that have noon, that particular place where the sun is vertical, those places that have morning twilight, those places that have evening twilight, and those places that have midnight.

Rule. Find the sun's declination (by Problem XX.) and mark it on the brass meridian; elevate the north or south pole, according as the sun's declination is north or south, so many degrees above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe *westward* as many hours as it wants of noon; but, if the given time be past noon, turn the globe eastward as many hours as the time is past noon: keep the globe in this position; then all places along the western edge of the horizon have the sun rising;

those places along the eastern edge have the sun setting; those under the brass meridian above the horizon, have noon; that particular place which stands under the sun's declination on the brass meridian, has the sun vertical; all places below the western edge of the horizon, within eighteen degrees, have morning twilight; those places which are below the eastern edge of the horizon, within eighteen degrees, have evening twilight; all places under the brass meridian below the horizon, have midnight; all the places above the horizon have day, and those below it have night or twilight.

EXAMPLES. 1. When it is fifty-two minutes past four o'clock in the morning at London on the fifth of March, find all places of the earth where the sun is rising, setting, &c. &c.

Answer. The sun's declination will be found to be $6\frac{1}{4}°$ south; therefore, elevate the south pole $6\frac{1}{4}°$ above the horizon. The given time being seven hours eight minutes before noon (=12 h. — 4 h. 52 m.) the globe must be turned towards the *west*, till the index has passed over seven hours eight minutes. Let the globe be fixed in this position, then,

The sun is rising at the western part of the White Sea, Petersburgh, the Morea in Turkey, &c.

Setting at the eastern coast of Kamtschatka, Jesus island, Palmerston island, &c. between the Friendly and Society islands.

Noon at the lake Baikal in Irkoutsk, Cochin China, Cambodia, Sunda islands, &c.

Vertical at Batavia.

Morning twilight at Sweden, part of Germany, the southern part of Italy, Sicily, the western coast of Africa along the Æthiopian Ocean &c.

Evening twilight at the north-west extremity of North America, the Sandwich islands, Society islands, &c.

Midnight at Labrador, New-York, western part of St. Domingo, Chili, and the western coast of South America.

Day at the eastern part of Russia in Europe, Turkey Egypt, the Cape of Good Hope, and all the eastern part of Africa, almost the whole of Asia, &c.

Night at the whole of North and South America, the western part of Africa, the British isles, France, Spain, Portugal, &c.

2. When it is four o'clock in the afternoon at London on the 25th of April, where is the sun rising, setting, &c. &c.?

Answer. The sun's declination being 13° north, the north pole must be elevated 13° above the horizon; and as the given time is four o'clock in the afternoon, the globe must be turned four hours towards the *east*, then the sun will be *rising* at O'why'hee, &c. *setting* at the Cape of Good Hope, &c.; it will be *noon* at Buenos Ayres, &c. the sun will be *vertical* at Barbadoes, and following the directions in the Problem, all the other places are readily found.

3. When it is ten o'clock in the morning at London on the longest day, to what countries is the sun rising, setting, &c. &c.?

4. When it is ten o'clock in the afternoon at Botany Bay on the 15th of October, where is the sun rising setting, &c. &c.?

5. When it is seven o'clock in the morning at Washington on the 17th of February, where is the sun rising setting, &c. &c.?

6. When it is midnight at the Cape of Good Hope on the 27th of July, where is the sun rising, setting, &c. &c.?

Problem XXVIII.

To find the time of the sun's rising, and setting, and length of the day and night, at any place not in the frigid zones.

Rule. Find the sun's declination (by Problem XX.) and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; bring the given place to the brass meridian, and set the index of the hour-circle to twelve; turn the globe *eastward* till the given place comes to the eastern semicircle of the horizon, and the number of hours passed over by the index will be the time of the sun's setting. deduct these hours from twelve, and you have the time of the sun's rising; because the sun rises as many hours before twelve as it sets after twelve. Double the time of the sun's setting gives the length of the day, and double the time of rising gives the length of the night.

By the same rule, the length of the *longest* day, at all places not in the frigid zones, may be readily found; for the longest day at all places in north latitude is on the 21st of June, or when the sun enters Cancer and the longest day at all places in south latitude is on the 21st of December, or when the sun enters the sign Capricorn.

OR,

Find the latitude of the given place, and elevate the north or south pole, according as the latitude is north or south, so many degrees above the horizon as are equal to the latitude; find the sun's place in the ecliptic (by Problem XX.) bring it to the brass meridian, and set the index of the hour circle to twelve; turn the globe *westward* till the sun's place come to the western semicircle of the horizon, and the number of hours passed over by the index will be the time of the sun's setting, and these hours taken from twelve will give the time of rising; then, as before, double the time of setting gives the length of the day, and double the time of rising gives the length of the night.

OR, BY THE ANALEMMA.

Find the latitude of the given place, and elevate the north or south pole, according as the latitude is north or south, the same number of degrees above the horizon; bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve: turn the globe *westward* till the day of the month on the analemma comes to the western semicircle of the horizon, and the number of hours passed over by the index will be the time of the sun's setting, &c. as above.

EXAMPLES. 1. What time does the sun rise and set at London on the 1st of June, and what is the length of the day and night?

Answer. The sun sets at 8 min. past 8, and rises at 52 min. past 3, the length of the day is 16 hours 16 minutes, and the length of the night 7 hours 44 minutes. The learner will readily perceive that if the time at which the sun rises be given, the time at which it sets, together with the length of the day and night, may be found without a globe; if the length of the day be given, the length of the night and the time the sun rises and sets may be found; if the length of the night be given, the length of the day and the time the sun rises and sets are easily known

2. At what time does the sun rise and set at the following places, on the respective days mentioned, and what is the length of the day and night?

London, 17th of May
Gibraltar, 22d July
Edinburgh, 29th January
Botany Bay, 20th February
Pekin, 20th April
Cape of Good Hope, 7th December
Cape Horn, 29th January
Washington, 15th Decem.
Petersburgh, 24th October
Constantinople, 18th Aug.

3. Find the time the sun rises and sets at every place on the surface of the globe on the 21st of March, and likewise on the 23d of September.

4. Required the length of the longest day and shortest night at the following places:

London	Paris	Pekin
Petersburg	Vienna	Cape Horn
Aberdeen	Berlin	Washington
Dublin	Buenos Ayres	Cape of Good Hope
Glasgow	Botany Bay	Copenhagen.

5. Required the length of the shortest day and longest night at the following places:

London	Lima	Paris
Archangel	Mexico	O'why'hee
O Taheitee	St. Helena	Lisbon
Quebec	Alexandria	Falkland islands.

6. How much longer is the 21st of June at Petersburg than at Alexandria?

7. How much longer is the 21st of December at Alexandria than at Petersburgh?

8. At what time does the sun rise and set at Spitzbergen on the 5th of April.

Problem XXIX.

The length of the day at any place, not in the frigid zones, being given, to find the sun's declination and the day of the month.

Rule. Bring the given place to the brass meridian and set the index to twelve: turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day; keep the globe from revolving on its axis, and elevate or depress one of the poles till the given place exactly coincides with the eastern semicircle of the horizon; the distance of the elevated pole from the horizon will be the sun's declination : mark the sun's declination, thus found, on the brass meridian : turn the globe on its axis, and observe what two points of the ecliptic pass under this mark; seek those points in the circle of signs on the horizon, and exactly against them, in the circle of months, stand the days of the months required.

OR,

Bring the meridian passing through Libra to coincide with the brass meridian, elevate the pole to the latitude of the place, and set the index of the hour-circle to twelve ; turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day, and mark where the meridian passing through Libra is cut by the eastern semicircle of the horizon ; bring this mark to the brass meridian, and the degree above it is the sun's declination ; with which proceed as above.

OR, BY THE ANALEMMA.

Bring the middle of the analemma to the brass meridian, elevate the pole to the latitude of the place, and set the index of the hour-circle to twelve ; turn the globe eastward till the index has passed over as many hours as are equal to half the length of the day ; the two days, on the analemma, which are cut by the eastern semicircle of the horizon, will be the days required ; and, by bringing the analemma to the brass meridian, the sun's declination will stand exactly above these days.

Examples. 1. What two days in the year are each sixteen hours long at London, and what is the sun's declination?

Answer. The 24th of May and the 17th of July. The sun's declination is about 21° north.

2. What two days of the year are each fourteen hours long at London?

3. On what two days of the year does the sun set at half-past seven o'clock at Edinburgh?

4. On what two days of the year does the sun rise at four o'clock at Petersburg?

5. What two nights of the year are each ten hours long at Copenhagen?

6. What day of the year at London is sixteen hours and a half long?

Problem XXX.

To find the length of the longest day at any place in the north frigid zone.

Rule. Bring the given place to the northern point of the horizon (by elevating or depressing the pole,) and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator, towards the north pole, and mark the place where the reckoning ends; turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark; find those points of the ecliptic in the circle of signs on the horizon, and exactly against them, in the circle of months, you will find the days on which the longest day begins and ends. The day preceding the 21st of June is that on which the longest day begins at the given place, and the day following the 21st of June is that on which the longest day ends: the time between these days is the length of the longest day.

Or, by the analemma.

Bring the given place to that part of the brass meridian which is numbered from the north pole towards the equator, and observe its distance in degrees from the pole; count the same number of degrees on the brass meridian from the equator towards the north pole, and mark where the reckoning ends; bring the analemma to the brass meridian, and the two days which stand under the above mark will point out the beginning and end of the longest day.

Examples. 1. What is the length of the longest day at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

Answer. The place is 18½° from the pole; the longest day begins on the 14th of May, and ends on the 30th of July; the day is therefore seventy-seven days long, that is, the sun does not set during seventy-seven revolutions of the earth on its axis.

2. What is the length of the longest day in the north of Spitzbergen, and on what days does it begin and end?

3. What is the length of the longest day at the northern extremity of Nova Zembla?

4. What is the length of the longest day at the north pole, and on what days does it begin and end?

Problem XXXI.

To find the length of the longest night at any place in the north frigid zone.

Rule Bring the given place to the northern point of the horizon (by elevating or depressing the pole,) and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator towards the south pole, and mark the place where the reckoning ends; turn the globe on its axis, and observe what two points of the ecliptic pass under the above mark; find those points of the ecliptic in the circle of signs on the horizon, and exactly against them in the circle of months, you will find the days on which the longest night begins and ends. The day preceding the 21st of December is that on which the longest night begins at the given place, and the day following the 21st of December is that on which the longest night ends: the time between these days is the length of the longest night.

Or, by the analemma.

Bring the given place to that part of the brass meridian which is numbered from the north pole towards the equator, and observe its distance in degrees from the pole; count the same number of degrees on the brass meridian from the equator towards the south pole, and mark where the reckoning ends; bring the analemma to the brass meridian, and the two days which stand under the above mark will point out the beginning and end of the longest night.

Examples. 1. What is the length of the longest night at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

Answer. The place is 18½° from the pole; the longest night begins on the 16th of November, and ends on the 27th of January: the night is therefore seventy-three days long, that is, the sun does not rise during seventy-three revolutions of the earth on its axis.

2. What is the length of the longest night at the north of Spitzbergen?

3. The Dutch wintered in Nova Zembla, latitude 76 degrees north, in the year 1596; on what day of the month did they lose sight of the sun; on what day of the month did he appear again; and how many days were they deprived of his appearance, setting aside the effect of refraction?

4. For how many days are the inhabitants of the northernmost extremity of Russia deprived of a sight of the sun?

Problem XXXII.

*To find the number of days which the sun rises and sets at any place in the north * frigid zone.*

Rule. Bring the given place to the northern point of the horizon, (by elevating or depressing the pole,) and observe its distance from the north pole on the brass meridian; count the same number of degrees on the brass meridian from the equator towards the poles northward and southward, and make marks where the reckoning ends; observe what two points of the eclip-

* The same might be found for a place in the south frigid zone, were that zone inhabited.

tic nearest to Aries pass under the above marks; these points will show (upon the horizon) the end of the longest night and the beginning of the longest day; during the time between these days the sun will rise and set every twenty-four hours; next observe what two points of the ecliptic, nearest to Libra, pass under the marks on the brass meridian; find these points, as before, in the circle of signs, and against them you will find the day on which the longest day ends at the given place, and the day on which the longest night begins; during the time between these days the sun will rise and set every twenty-four hours.

Or,

Find the length of the longest day at the given place (by Prob. XXX.) and the length of the longest night (by Prob. XXXI.) add these together, and subtract the sum from 365 days, the length of the year, the remainder will show the number of days which the sun rises and sets at that place.

Or, by the analemma.

Find how many degrees the given place is from the north pole, and mark those degrees upon the brass meridian on both sides of the equator; observe what four days on the analemma stand under the marks on the brass meridian; the time between those two days on the left hand part of the analemma (reckoning towards the north pole) will be the number of days on which the sun rises and sets, between the end of the longest night and the beginning of the longest day and the time between the two days on the right-hand part of the analemma (reckoning towards the south pole) will be the number of days on which the sun rises and sets, between the end of the longest day and the beginning of the longest night.

EXAMPLES. 1. How many days in the year does the sun rise and set at the North Cape, in the island of Maggeroe, in latitude 71° 30′ north?

Answer. The place is 18½° from the pole, the two points in the ecliptic, *nearest to Aries*, which pass under 18½° on the brass meridian, are 8° in ♒, answering to the 27th of January, and 24° in ♉, answering to the 14th of May. Hence the sun rises and sets for 107 days, viz. from the end of the longest night, which happens on the 27th of January, to the beginning of the longest day, which happens on the 14th of May. *Secondly*, the two points in the ecliptic, *nearest to Libra*, which pass under 18½° on the brass meridian, are 8° in ♌, answering to the 30th of July, and 24° in ♏, answering to the 15th of November. Hence the sun rises and sets for 108 days, viz. from the end of the longest day, which happens on the 30th of July, to the beginning of the longest night, which happens on the 15th of November; so that the whole time of the sun's rising and setting is 215 days.

OR, THUS:

The length of the longest day, by Example 1st, Prob. XXX. is 77 days; the length of the longest night by Example 1st, Prob. XXXI. is 73 days; the sum of these is 150, which, deducted from 365, leaves 215 days as above.

2. How many days in the year does the sun rise and set at the north of Spitzbergen?

3. How many days does the sun rise and set at Greenland, in latitude 75° north?

4. How many days does the sun rise and set at the northern extremity of Russia in Asia?

Problem XXXIII.

To find in what degree of north latitude, on any day between the 21st of March and the 21st of June, or in what degree of south latitude, on any day between the 23d of September and the 21st of December, the sun begins to shine constantly without setting ; and also in what latitude in the opposite hemisphere he begins to be totally absent.

Rule. Find the sun's declination (by Prob. XX.) and count the same number of degrees from the north pole towards the equator, if the declination be north, or from the south pole, if it be south, and mark the point where the reckoning ends ; turn the globe on its axis, and all places passing under this mark are those in which the sun begins to shine constantly without setting at that time : the same number of degrees from the contrary pole will point out all the places where twilight or total darkness begins.

Examples. 1. In what latitude north, and at what places, does the sun begin to shine without setting during several revolutions of the earth on its axis, on the 14th of May ?

Answer. The sun's declination is 18½° north, therefore all places in latitude 71½° north will be the places sought, viz. the North Cape in Lapland, the southern part of Nova Zembla, Icy Cape, &c.

2. In what latitude south does the sun begin to shine without setting on the 18th of October, and in what latitude north does he begin to be totally absent ?

Answer. The sun's declination is 10° south, therefore he begins to shine constantly in latitude 80° south, where there are no inhabitants known, and to be totally absent in latitude 80° north at Spitzbergen.

3 In what latitude does the sun begin to shine without setting on the 20th of April?

4. In what latitude north does the sun begin to shine without setting on the 1st of June, and in what degree of south latitude does he begin to be totally absent?

Problem XXXIV.

Any number of days, not exceeding 186, being given, to find the parallel of north latitude in which the sun does not set for that time.

Rule. Count half the number of days from the 21st of June on the horizon, eastward or westward, and opposite to the last day you will find the sun's place in the circle of signs: look for the sign and degree on the ecliptic, which bring to the brass meridian, and observe the sun's declination; reckon the same number of degrees from the north pole (on that part of the brass meridian which is numbered from the equator towards the poles) and you will have the latitude sought.

Examples. 1. In what degree of north latitude, and at what places, does the sun continue above the horizon for seventy-seven days?

Answer. Half the number of days is 38½, and if reckoned backward or towards the east, from the 21st of June, will answer to the 14th of May; and if counted forward, or towards the west, will answer to the 30th of July; on either of which days the sun's declination is 18½ degrees north, consequently the places sought are 18½ degrees from the north pole, or in latitude 71½ degrees north; answering to the North Cape in Lapland, the south part of Nova Zembla, Icy Cape, &c.

2. In what degree of north latitude is the longest day 134 days, or 3216 hours in length?

3. In what degree of north latitude does the sun continue above the horizon for 2160 hours?

4. In what degree of north latitude does the sun continue above the horizon for 1152 hours?

Problem XXXV.

To find the beginning, end, and duration of twilight at any given place on any given day.

Rule. Find the sun's declination for the given day (by Problem XX.) and elevate the north or south pole, according as the declination is north or south, so many degrees above the horizon as are equal to the sun's declination; screw the quadrant of altitude on the brass meridian, over the degree of the sun's declination; bring the given place to the brass meridian, and set the index of the hour-circle to twelve: turn the globe eastward till the given place comes to the horizon, and the hours passed over by the index will show the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe eastward, till the given place coincides with 18° on the quadrant of altitude below the horizon, and the hours passed over by the index, from 12, will show when evening twilight ends. The time when evening twilight ends, subtracted from 12, will show the beginning of morning twilight.

Or, thus:

Elevate the north or south pole, according as the latitude of the given place is north or south, so many degrees above the horizon as are equal to the latitude; find the sun's place in the ecliptic, bring it to the brass meridian, set the index of the hour-circle to twelve and screw the quadrant of altitude upon the brass meridian over the given latitude: turn the globe westward on its axis till the sun's place comes to the western edge of the horizon, and the hours passed over by the index will show the time of the sun's setting, or the beginning of evening twilight; continue the motion of the globe westward till the sun's place coincides with 18° on the quadrant of altitude below the horizon, the time passed over by the index of the hour-circle, from the time of the sun's setting, will show the duration of evening twilight.

Or, by the analemma.

Elevate the pole to the latitude of the place, as above, and screw the quadrant of altitude upon the brass meridian over the degree of latitude; bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve; turn the globe westward till the given day of the month, on the analemma, comes to the western edge of the horizon, and the hours passed over by the index will show the time of the sun's setting, or the beginning of evening twilight: continue the motion of the globe westward till the given day of the month coincides with 18° on the quadrant below the horizon, the time passed over by the index, from the time of the sun's setting, will show the duration of evening twilight.

Examples. 1. Required the beginning, end, and duration of morning and evening twilight at London on the 19th of April?

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Answer. The sun sets at two minutes past seven, and evening twilight ends at nineteen minutes past nine; consequently morning twilight begins at (12 h. — 9 h. 19 m. =) 2 h. 41 m. and ends at (12 h. — 7 h 2 m. =) 4 h. 58 m.; the duration of twilight is 2 h. and 17 minutes.

2. What is the duration of twilight at London on the 23d of September, what time does dark night begin, and at what time does day break in the morning?

Answer. The sun sets at six o'clock, and the duration of twilight is two hours; consequently the evening twilight ends at eight o'clock, and the morning twilight begins at four.

3. Required the beginning, end, and duration of morning and evening twilight at London on the 25th of August?

4. Required the beginning, end, and duration of morning and evening twilight at Edinburgh on the 20th of February?

5. Required the beginning, end, and duration of morning and evening twilight at Cape Horn on the 20th of February?

6. Required the beginning, end, and duration of morning and evening twilight at Madras on the 15th of June?

Problem XXXVI.

To find the beginning, end, and duration of constant day or twilight at any place.

Rule Find the latitude of the given place, and add 18° to that latitude; count the number of degrees correspondent to the sum, on that part of the brass meridian which is numbered from the pole towards the equator, mark where the reckoning ends, and observe what two points of the ecliptic pass under the mark;

that point wherein the sun's declination is increasing will show on the horizon the beginning of constant twilight; and that point wherein the sun's declination is decreasing, will show the end of constant twilight.

EXAMPLES. 1. When do we begin to have constant day or twilight at London, and how long does it continue?

Answer. The latitude of London is $51\frac{1}{2}$ degrees north, to which add 18 degrees, the sum is $69\frac{1}{2}$, the two points of the ecliptic which pass under $69\frac{1}{2}$ are two degrees in ♊, answering to the 22d of May, and 29 degrees in ♋, answering to the 21st of July; so that, from the 22d of May to the 21st of July the sun never descends 18 degrees below the horizon of London.

2. When do the inhabitants of the Shetland islands cease to have constant day or twilight?

3. Can twilight ever continue from sun-set to sun-rise at Madrid?

4. When does constant day or twilight begin at Spitzbergen?

5. What is the duration of constant day or twilight at the North Cape in Lapland, and on what day, after their long winter's night, do the sun's rays first enter the atmosphere?

PROBLEM XXXVII.

To find the duration of twilight at the north pole.

RULE. Elevate the north pole so that the equator may coincide with the horizon; observe what point of the ecliptic nearest to Libra passes under 18° below the horizon, reckoned on the brass meridian, and find the day of the month correspondent thereto, the time elapsed from the 23d of September to this time will be the duration of evening twilight. Secondly, observe what point of the ecliptic, nearest to Aries, passes under 18° below the horizon, reckoned on the brass meridian, and find the day of the month correspondent thereto; the time elapsed from that day to the 21st of March will be the duration of morning twilight.

Example. What is the duration of twilight at the north pole, and what is the duration of dark night there?

Answer. The point of the ecliptic nearest to Libra which passes under 18 degrees below the horizon, is 22 degrees in ♏, answering to the 13th of November; hence the evening twilight continues from the 23d of September (the end of the longest day) to the 13th of November, (the beginning of dark night) being 51 days. The point of the ecliptic nearest to Aries which passes under 18 degrees below the horizon is 9 degrees in ♒, answering to the 29th of January; hence the morning twilight continues from the 29th of January to the 21st of March (the beginning of the longest day) being 51 days. From the 23d of September to the 21st of March are 179 days, from which deduct 102 (= 51 × 2,) the remainder is 77 days, the duration of total darkness at the north pole; but, even during this short period, the moon and the Aurora Borealis shine with uncommon splendour.

Problem XXXVIII.

To find in what climate any given place on the globe is situated.

Rule. 1. If the place be not in the frigid zone find the length of the longest day at that place (by Problem XXVIII.) and subtract twelve hours therefrom; the number of half hours in the remainder will show the climate.

2. If the place be in the frigid zone,* find the length

* The climates between the polar circles and the poles were unknown to the ancient geographers; they reckoned only seven climates

of the longest day at that place (by Problem XXX.) and if that be less than thirty days, the place is in the twenty-fifth climate, or the *first* within the polar circle. If more than thirty and less than sixty, it is in the twenty-sixth climate, or the *second* within the polar circle; if more than sixty, and less than ninety, it is in the twenty-seventh climate, or the *third* within the polar circle, &c.

EXAMPLES. 1. In what climate is London, and what other remarkable places are situated in the same climate?

Answer. The longest day in London is 16½ hours, if we deduct 12 therefrom, the remainder will be 4½ hours, or nine half hours; hence London is in the ninth climate north of the equator; and as all places in or near the same latitude are in the same climate, we shall find Amsterdam, Dresden, Warsaw, Irkoutsk, the southern part of the peninsula of Kamtschatka, Nootka Sound, the south of Hudson's Bay, the north of Newfoundland, &c. to be in the same climate as London.

2. In what climate is the North Cape in the island of Maggeroe, latitude 71° 30′ north?

north of the equator. The middle of the first northern climate they made to pass through *Meroe*, a city of Ethiopia, built by Cambyses on an island in the Nile, nearly under the tropic of Cancer; the second through *Syene*, a city of Thebais in Upper Egypt, near the cataracts of the Nile; the third through *Alexandria;* the fourth through *Rhodes;* the fifth through *Rome* or the *Hellespont;* the sixth through the mouth of the *Borysthenes* or *Dnieper;* and the seventh through the *Riphhæan mountains,* supposed to be situated near the source of the Tanais or Don river. The southern parts of the earth being in a great measure unknown, the climates received their names from the northern ones and not from particular towns or places. Thus the climate, which was supposed to be at the same distance from the equator southward Meroe was northward, was called *Antidiameroes,* or the opposite climate to Meroe; *Antidiasyenes* was the opposite climate to Syenes &c.

Answer. The length of the longest day is 77 days; these days divided by 30, give two months for the quotient, and a remainder of 17 days; hence the place is in the *third* climate within the polar circle, or the 27th climate reckoning from the equator. The southern part of Nova Zembla, the northern part of Siberia, James' Island, Baffin's Bay the northern part of Greenland, &c. are in the same climate.

3. In what climate is Edinburgh, and what other places are situated in the same climate?

4. In what climate is the north of Spitzbergen?

5. In what climate is Cape Horn?

6. In what climate is Botany Bay, and what other places are situated in the same climate?

Problem XXXIX.

To find the breadths of the several climates between the equator and the polar circles.

Rule. For the northern climates. Elevate the north pole 23½° above the northern point of the horizon; bring the sign Cancer to the meridian, and set the index to twelve; turn the globe eastward on its axis till the index has passed over a quarter of an hour; observe that particular point of the meridian passing through Libra, which is cut by the horizon, and at the point of intersection make a mark with a pencil; continue the motion of the globe eastward till the index has passed over another quarter of an hour, and make a second mark: proceed thus till the meridian passing through Libra* will no longer cut the horizon; the several

* On Adams' and Cary's globes, the meridian passing through Libra is divided into degrees, in the same manner as the brass meridian is divided; the horizon will, therefore, cut this meridian in the several degrees answering to the end of each climate, without the trouble of bringing it to the brass meridian, or marking the globe.

marks brought to the brass meridian will point out the latitude where each climate ends.

EXAMPLES. 1. What is the breadth of the ninth north climate, and what places are situated within it?

Answer. The breadth of the 9th climate is 2° 57′; it begins in latitude 49° 2′ north, and ends in latitude 51° 59′ north, and all places situated within this space are in the same climate. The places will be nearly the same as those enumerated in the first example to the preceding problem.

2. What is the breadth of the second climate, and in what latitude does it begin and end?

3. Required the beginning, end, and breadth of the fifth climate?

4. What is the breadth of the seventh climate north of the equator, in what latitude does it begin and end, and what places are situated within it?

5. What is the breadth of the climate in which Petersburg is situated?

6. What is the breadth of the climate in which Mount Heckla is situated?

PROBLEM XL.

To find that part of the equation of time which depends on the obliquity of the ecliptic.

RULE. Find the sun's place in the ecliptic, and bring it to the brass meridian; count the number of degrees from Aries to the brass meridian, on the equator and on the ecliptic; the difference, reckoning four minutes of time to a degree, is the equation of time. If the number of the degrees on the ecliptic exceed those on the equator, the sun is faster than the clock; but if the number of degrees on the equator exceed those on the ecliptic, the sun is slower than the clock.

Note. The equation of time, or difference between the time shown by a well-regulated clock, and a true sun-dial, depends upon two causes, viz. the obliquity of the ecliptic, and the unequal motion of the earth in its orbit. The former of these causes may be explained by the above Problem. If two suns were to set off at the same time from the point Aries, and move over equal spaces in equal time, the one on the ecliptic, the other on the equator, it is evident they would never come to the meridian together, except at the time of the equinoxes, and on the longest and shortest days. The annexed table shows how much the sun is faster or slower than the clock ought to be, so far as the variation depends on the obliquity of the ecliptic only. The signs of the first and third quadrants of the ecliptic are at the top of the table, and the degrees in these signs on the left hand; in any of these signs the sun is faster than the clock. The signs of the second and third quadrants are at the bottom of the table, and the degrees in these signs at the right hand; in any of these signs the sun is lower than the clock.

Thus, when the sun is in 20 degrees of ♉ or ♏, it is 9 minutes 50 seconds faster than the clock, and, when the sun is in 18 degrees of ♋ or ♑, it is 6 minutes 2 seconds slower than the clock.

Sun *faster than the* Clock *in*				
Degrees.	♈ ♎	♉ ♏	♊ ♐	1 Qu 3 Qu
	M. S.	M. S.	M. S.	
0	0 0	8 24	8 46	30
1	0 20	8 35	8 36	29
2	0 40	8 45	8 25	28
3	1 0	8 54	8 14	27
4	1 19	9 3	8 1	26
5	1 39	9 11	7 49	25
6	1 59	9 18	7 35	24
7	2 18	9 24	7 21	23
8	2 37	9 31	7 6	22
9	2 56	9 36	6 51	21
10	3 16	9 41	6 35	20
11	3 34	9 45	6 19	19
12	3 53	9 49	6 2	18
13	4 11	9 51	5 45	17
14	4 29	9 53	5 27	16
15	4 47	9 54	5 9	15
16	5 4	9 55	4 50	14
17	5 21	9 55	4 31	13
18	5 38	9 54	4 12	12
19	5 54	9 52	3 52	11
20	6 10	9 50	3 32	10
21	6 26	9 47	3 12	9
22	6 41	9 43	2 51	8
23	6 35	9 38	2 30	7
24	7 9	9 33	2 9	6
25	7 23	9 27	1 48	5
26	7 36	9 20	1 27	4
27	7 49	9 13	1 5	3
28	8 1	9 5	0 43	2
29	8 13	8 56	0 22	1
30	8 24	8 46	0 0	0
2 Qu 4 Qu	♍ ♓	♌ ♒	♋ ♑	Deg.
Sun *slower than the* Clock				

Examples. 1. What is the equation of time on the 17th of July?

Answer. The degrees on the equator exceed the degrees on the ecliptic by two; hence the sun is eight minutes slower than the clock.

2. On what four days of the year is the equation of time nothing?

3. What is the equation of time dependant on the obliquity of the ecliptic on the 27th of October?

4. When the sun is in 18° of Aries, what is the equation of time?

Problem XLI.

To find the sun's meridian altitude at any time of the year at any given place.

Rule. Find the sun's declination, and elevate the pole to that declination; bring the given place to the brass meridian, and count the number of degrees on the brass meridian (the nearest) to the horizon; these degrees will show the sun's meridian altitude.

Note. *The sun's altitude may be found at any particular hour, in the following manner.*

Find the sun's declination, and elevate the pole to that declination; bring the *given* place to the brass meridian and set the index to 12: then, if the given time be before noon, turn the globe westward as many hours as the time wants of noon; if the given time be past noon, turn the globe eastward as many hours as the time is past noon. Keep the globe fixed in this position, and screw the quadrant of altitude on the brass meridian over the sun's declination; bring the graduated edge of the quadrant to coincide with the given place, and the number of degrees between that place and the horizon will show the sun's altitude.

Or,

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; count the number of degrees contained on the brass meridian between the sun's place and the horizon, and they will show the altitude.

To find the sun's *altitude* at any hour, see Problem XLIV.

Or, by the analemma.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the day of the month on the analemma, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; count the number of degrees contained on the brass meridian between the given day of the month and the horizon, and they will show the altitude.

To find the sun's *altitude* at any hour, see Problem XLIV.

Examples. 1. What is the sun's meridian altitude at London on the 21st of June?

Answer. 62 degrees.

2. What is the sun's meridian altitude at London on the 21st of March?

3. What is the sun's least meridian altitude at London?

4. What is the sun's greatest meridian altitude at Cape Horn?

5. What is the sun's meridian altitude at Madras on the 20th of June?

6. What is the sun's meridian altitude at Bencoolen on the 15th of January?

EXAMPLES *to the note.*

1. What is the sun's altitude at Madrid on the 24th of August, at 11 o'clock in the morning?

Answer. The sun's declination is 11¼ degrees north; by elevating the north pole 11¼ degrees above the horizon, and turning the globe so that Madrid may be *one* hour westward of the meridian, the sun's altitude will be found to be 57¼ degrees.

2. What is the sun's altitude at London at 3 o'clock in the afternoon on the 25th of April?

3. What is the sun's altitude at Rome on the 16th of January at 10 o'clock in the morning?

4. Required the sun's altitude at Buenos Ayres on the 21st of December at two o'clock in the afternoon?

PROBLEM XLII.

When it is midnight at any place in the temperate or torrid zones, to find the sun's altitude at any place (on the same meridian) in the north frigid zone, where the sun does not descend below the horizon.

RULE. Find the sun's declination for the given day and elevate the pole to that declination; bring the place (in the frigid zone) to that part of the brass meridian which is numbered from the north pole towards the equator, and the number of degrees between it and the horizon will be the sun's altitude.

OR,

Elevate the north pole so many degrees above the horizon as are equal to the latitude of the place in the frigid zone; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour-circle to twelve; turn the globe on its axis till the index points to the other twelve; and the number of degrees between the sun's place and the horizon, counted on the brass meridian towards that part of the horizon marked north, will be the sun's altitude.

Examples. 1. What is the sun's altitude at the North Cape in Lapland, when it is midnight at Alexandria in Egypt on the 21st of June?

Answer. 5 degrees.

2. When it is midnight to the inhabitants of the island of Sicily on the 22d of May, what is the sun's altitude at the north of Spitzbergen, in latitude 80° north?

3. What is the sun's altitude at the north-east of Nova Zembla, when it is midnight at Tobolsk, on the 15th of July?

4. What is the sun's altitude at the north of Baffin's Bay, when it is midnight at Buenos Ayres, on the 28th of May?

Problem XLIII.

To find the sun's amplitude at any place.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; find the sun's place in the ecliptic, and bring it to the eastern semicircle of the horizon; the number of degrees from the sun's place to the east point of the horizon will be the rising amplitude; bring the sun's place to the western semicircle of the horizon, and the number of degrees from the sun's place to the west point of the horizon will be the setting amplitude.

OR, BY THE ANALEMMA.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; bring the day of the month on the analemma to the eastern semicircle of the horizon: the number of degrees from the day of the month to the east point of the horizon will be the rising amplitude: bring the day of the month to the western semicircle of the horizon, and the number of degrees from the day of the month to the west point of the horizon will be the setting amplitude.

EXAMPLES. 1. What is the sun's amplitude at London on the 21st of June?

Answer. 39° 48′ to the north of the east, and 39° 48′ to the north of the west.

2. On what point of the compass does the sun rise and set at London on the 17th of May?

3. On what point of the compass does the sun rise and set at the Cape of Good Hope on the 21st of December?

4. On what point of the compass does the sun rise and set on the 21st of March?

5. On what point of the compass does the sun rise and set at Washington on the 21st of October?

6. On what point of the compass does the sun rise and set at Petersburg on the 18th of December?

7. On December 22d, 1827, in latitude 31° 38′ S. and longitude 83° W., if the sun set on the S. W. point of the compass, what is the variation?

8. On the 15th of May 1827, if the sun rise E. by N. in latitude 33° 15′ N. and longitude 18° W., what is the variation of the compass?

Problem XLIV.

To find the sun's azimuth and his altitude at any place, the day and hour being given.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; then if the given time be before noon, turn the globe eastward* as many hours as it wants of noon; but, if the given time be past noon, turn the globe westward as many hours as it is past noon, bring the graduated edge of the quadrant of altitude to coincide with the sun's place, then the number of degrees on the horizon, reckoned from the north or south point thereof to the graduated edge of the quadrant, will show the azimuth; and the number of degrees on the quadrant, counting from the horizon to the sun's place, will be the sun's altitude.

* Whenever the pole is elevated for the latitude of the place, the proper motion of the globe is from *east to west*, and the *sun* is on the east side of the brass meridian in the morning, and on the west side in the afternoon; but when the pole is elevated for the sun's declination, the motion is from *west to east*, and the *place* is on the west side of the meridian in the morning, and on the east side in the afternoon.

Or, by the analemma.

Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe eastward on its axis as many hours as it wants of noon; but, if the given time be past noon, turn the globe westward as many hours as it is past noon; bring the graduated edge of the quadrant of altitude to coincide with the day of the month on the analemma, then the number of degrees on the horizon, reckoned from the north or south point thereof to the graduated edge of the quadrant, will show the azimuth; and the number of degrees on the quadrant, counting from the horizon to the day of the month, will be the sun's altitude.

Examples. 1. What is the sun's altitude, and his azimuth from the north, at London, on the 1st of May, at ten o'clock in the morning?

Answer. The altitude is 47°, and the azimuth from the north 136° or from the south 44°.

2. What is the sun's altitude and azimuth at Petersburg on the 13th of August, at half past five o'clock in the morning?

3. What is the sun's azimuth and altitude at Antigua, on the 21st of June, at half past six in the morning, and at half past ten?

4. At Barbadoes on the 21st of June, required the sun's azimuth and altitude at 8 minutes past 6, and at

$\frac{3}{4}$ past 9 in the morning: also at $\frac{1}{4}$ past 2, and at 52 minutes past 5 in the afternoon.

5. On the 13th of August at half past eight o'clock in the morning, at sea, in latitude 57° N. the observed azimuth of the sun was S. 40° 14′ E., what was the sun's altitude, his true azimuth, and the variation of the compass?

6. On the 14th of January, in latitude 33° 52′ S., at half past three o'clock in the afternoon, the sun's magnetic azimuth was observed to be N. 63° 51′ W.; what was the true azimuth, the variation of the compass, and the sun's altitude?

Problem XLV.

The latitude of the place, day of the month, and the sun's altitude being given, to find the sun's azimuth and the hour of the day.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian, over that latitude; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour-circle to twelve; turn the globe on its axis till the sun's place in the ecliptic coincides with the given degree of altitude on the quadrant; the hours passed over by the index of the hour-circle will show the time from noon, and the azimuth will be found on the horizon, as in the preceding problem.

Or, by the analemma.

Elevate the pole to the latitude of the place, and screw the quadrant of altitude over that latitude: bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to twelve; move the globe and the quadrant till the day of the month coincides with the given altitude, the hours passed over by the index will show the time from noon, and the azimuth will be found in the horizon as before.

EXAMPLES. 1. At what hour of the day on the 21st of March is the sun's altitude $22\frac{1}{4}°$ at London, and what is his azimuth? The observation being made in the afternoon.

Answer. The time from noon will be found to be 3 hours 30 minutes, and the azimuth 59° 1′ from the south towards the west. Had the observations been made before noon, the time from noon would have been $3\frac{1}{2}$ hours, viz. it would have been 30 minutes past eight in the morning, and the azimuth would have been 59° 1′ from the south towards the east.

2. At what hour on the 9th of March is the sun's altitude 25° at London, and what is his azimuth? The observation being made in the forenoon.

3. At what hour on the 18th of May is the sun's altitude 30° at Lisbon, and what is the azimuth? The observation being made in the afternoon.

4. Walking along the side of Queen-square in London on the 5th of August in the forenoon, I observed the shadows of the iron-rails to be exactly the same length as the rails themselves; pray what o'clock was it, and on what point of the compass did the shadows of the rails fall?

5. At what hour of the day on the 20th of September, is the sun's altitude 21° at Quebec, and what is its azimuth, the observation being made in the morning?

6. At what hour on the 15th of June is the sun s al titude 30° at Philadelphia, and what is the azimuth the observation being made in the afternoon ?

Problem XLVI.

Given the latitude of the place, and the day of the month to find at what hour the sun is due east or west.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve ; screw the quadrant of altitude on the brass meridian, over the given latitude, and move the lower end of it to the east point of the horizon ; hold the quadrant in this position, and move the globe on its axis till the sun's place comes to the graduated edge of the qua drant; the hours passed over by the index from twelve will be the time from noon when the sun is due east, and at the same time from noon he will be due west.

Examples. 1. At what hour will the sun be due east at London on the 19th of May ; at what hour will he be due west; and what will his altitude be at these times ?

Answer. The time from 12 when the sun is due east, is 4 hours 54 minutes ; hence the sun is due east at six minutes past seven o'clock in the morning, and due west at 54 minutes past four in the afternoon ; the sun's altitude will be found at the same time, as in Problem XLIV In this example it is 25° 26′.

2. At what hours will the sun be due east and west at London on the 21st of June, and on the 21st of December ; and what will be his altitude above the hori zon on the 21st of June ?

3. Find at what hours the sun will be due east and west, not only at London, but at every place on the surface of the globe, on the 21st of March and on the 23d of September?

4. At what hours is the sun due east and west at Buenos Ayres on the 21st of December?

Problem XLVII.

Given the sun's meridian altitude, and the day of the month, to find the latitude of the place.

Rule. Find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; then, if the sun was south of the observer when the altitude was taken, count the number of degrees from the sun's place on the brass meridian towards the south point of the horizon, and mark where the reckoning ends; bring this mark to coincide with the south point of the horizon, and the elevation of the north pole will show the latitude. If the sun was north of the observer when the altitude was taken, the degrees must be counted in a similar manner, from the sun's place towards the north point of the horizon, and the elevation of the south pole will show the latitude.

Or, without a globe.

Subtract the sun's altitude from ninety degrees, the remainder is the zenith distance. If the sun be south when his altitude is taken, call the zenith distance north; but, if north, call it south; find the sun's declination in an ephemeris or a table of the sun's declination, and mark whether it be north or south; then, if the zenith distance, and declination have the same name, their sum is the latitude, but, if they have contrary names, their difference is the latitude, and it is always of the same name with the greater of the two quantities.

Examples. On the 10th of May, 1827, I observed the sun's meridian altitude to be 50°, and it was south of me at that time; required the latitude of the place?

Answer. 57° 29′ north.

By calculation.

90° 0′
50 0 *S.*, sun's altitude at noon.

40 0 *N.*, the zenith's distance.
17 29 *N.*, the sun's declination 10th May 1827.

57 29 *N.*, the latitude sought.

2. On the 10th of May, 1827, the sun's meridian altitude was observed to be 50°, and it was north of the observer at that time; required the latitude of the place?

Answer. 22° 23′ south.

By calculation.

99° 0′
50 0 *N.*, sun's altitude at noon.

40 0 *S.*, the zenith's distance.
17 29 *N.*, the sun's declination 10th May 1827.

22 31 *S.*, the latitude sought.

3. On the 5th of August, 1827, the sun's meridian altitude was observed to be 74° 30′ north of the observer; what was the latitude?

4. On the 19th of November, 1827, the sun's meridian altitude was observed to be 40° south of the observer; what was the latitude?

5. At a certain place, where the clocks are two hours faster than at London, the sun's meridian altitude was observed to be 30 degrees to the south of the observer on the 21st of March; required the place?

6. At the place where the clocks are 5 hours slower than at London, the sun's meridian altitude was observed to be 60° to the south of the observer on the 16th of April, 1827; required the place?

Problem XLVIII.

The length of the longest day at any place, not within the polar circles, being given, to find the latitude of that place.

Rule. Bring the first point of Cancer or Capricorn to the brass meridian (according as the place is on the north or south side of the equator,) and set the index of the hour-circle to twelve: turn the globe westward on its axis till the index of the hour-circle has passed over as many hours as are equal to half the length of the day; elevate or depress the pole till the sun's place (viz. Cancer or Capricorn) comes to the horizon; then the elevation of the pole will show the latitude.

Note. This problem will answer for any day in the year, as well as the longest day, by bringing the sun's place to the brass meridian and proceeding as above.

Or, Bring the middle of the analemma to the brass meridian, and set the index of the hour-circle to 12; turn the globe westward on its axis till the index has passed over as many hours as are equal to half the length of the day; elevate or depress the pole till the day of the month coincides with the horizon, then the elevation of the pole will show the latitude.

EXAMPLES. 1. In what degree of north latitude, and at what places is the length of the longest day $16\frac{1}{2}$ hours?

Answer. In latitude 52°, and all places situated on, or near that parallel of latitude, have the same length of the day.

2. In what degree of south latitude, and at what places is the longest day 14 hours?

3. In what degree of north latitude is the length of the longest day three times the length of the shortest night?

4. There is a town in Norway where the longest day is five times the length of the shortest night; pray what is the name of the town?

5. In what latitude north does the sun set at seven o'clock on the 5th of April?

6. In what latitude south does the sun rise at five o'clock on the 25th of November?

7. In what latitude north is the 20th of May 16 hours long?

8. In what latitude north is the night of the 15th of August 10 hours long?

PROBLEM XLIX.

The latitude of a place and the day of the month being given, to find how much the sun's declination must vary to make the day an hour longer or shorter than the given day.

RULE. Find the sun's declination for the given day, and *elevate* the pole to that declination: bring the given place to the brass meridian, and set the index of the hour circle to twelve: turn the globe eastward on its axis till the given place comes to the horizon, and observe the hours passed over by the index. Then, if the days be increasing, continue the motion of the globe eastward till the index has passed over another half hour, and raise or depress the pole till the place comes again into the horizon, the elevation of the pole will show the sun's declination when the day is an hour longer than the given day; but, if the days be decreasing, after the place is brought to the eastern part of the horizon, turn the globe westward till the index has passed over half an hour, then raise or depress the pole till the place comes a second time into the horizon, the last elevation of the pole will show the sun's declination when the day is an hour shorter than the given day.

OR,

Elevate the pole to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; turn the globe westward on its axis till the sun's place comes to the horizon, and observe the hours passed over by the index; then, if the days be increasing, continue the motion of the globe westward till the index has passed over another half hour, and observe what point of the ecliptic is cut by the horizon; that point will show the sun's place when the day is an hour longer than the given day, whence the declination is readily found: but, if the days be decreasing, turn the globe eastward till the index has passed over half an hour, and observe what point of the ecliptic is cut by the horizon; that point will show the sun's place when the day is an hour shorter than the given day.

Or, by the analemma.

Proceed exactly the same as above, only, instead of bringing the sun's place to the brass meridian, bring the analemma there, and instead of the sun's place, use the day of the month on the analemma.

Examples. 1. How much must the sun's declination vary that the day at London may be increased one hour from the 24th of February?

Answer. On the 24th of February the sun's declination is 9° 38′ south, and the sun sets at a quarter past five; when the sun sets at three quarters past five, his declination will be found to be about $4\frac{1}{4}$° south, answering to the tenth of March: hence the declination has decreased 5° 23′, and the days have increased 1 hour in 14 days.

2. How much must the sun's declination vary that the day at London may decrease *one* hour in length from the 26th of July?

Answer. The sun's declination on the 26th of July is 19° 38 north, and the sun sets at 49 min. past seven; when the sun sets at 19 min. past seven, his declination will be found to be 14° 43′ north, answering to the 13th of August: hence the declination has decreased 5° 55′, and the days have decreased *one* hour in 18 days

3. How much must the sun's declination vary from the 5th of April, that the day at Petersburg may increase *one* hour?

4. How much must the sun's declination vary from the 4th of October, that the day at Stockholm may decrease *one* hour?

5. What is the difference in the sun's declination,

when he rises at seven o'clock at Petersburg, and when he sets at nine?

Problem L.

To find the sun's right ascension, oblique ascension, oblique descension, ascensional difference, and time of rising and setting at any place.

Rule. Find the sun's place in the ecliptic, and bring it to that part of the brass meridian which is numbered from the equator towards the poles; the degree on the equator cut by the graduated edge of the brass meridian, reckoning from the point Aries eastward, will be the sun's right ascension.

Elevate the poles so many degrees above the horizon as are equal to the latitude of the place, bring the sun's place in the ecliptic to the eastern part of the horizon, and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique ascension. Bring the sun's place in the ecliptic to the western part of the horizon, and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the sun's oblique descension.

Find the difference between the sun's right and oblique ascension; or, which is the same thing, the difference between the right ascension and oblique descension, and turn this difference into time by multiplying by 4: then, if the sun's declination and the latitude of the place be both of the same name, viz. both north or both south, the sun rises before six and sets after six, by a space of time equal to the ascensional difference; but if the sun's declination and the latitude be of contrary names, viz. the one north and the other south, the sun rises after six and sets before six.

Examples. 1. Required the sun's right ascension, oblique ascension, oblique descension, ascensional difference, and time of rising and setting at London, on the 15th of April?

Answer. The right ascension is 23° 30′, the oblique ascension is 9° 45′, the ascensional difference (23° 30′—9° 45′ =) 13° 45′, or 55 minutes of time; consequently the sun rises 55 minutes before 6, or 5 min. past 5, and sets 55 min. past 6. The oblique descension is 37° 15′; consequently the descensional difference is (37° 15′—23° 30′ =) 13° 45′, the same as the ascensional difference.

2. What are the sun's right ascension, oblique ascension, and oblique descension, on the 27th of October at London; what is the ascensional difference, and at what time does the sun rise and set?

3. What are the sun's right ascension, declination, oblique ascension, rising amplitude, oblique descension, and setting amplitude at London, on the 1st of May; what is the ascensional difference, and at what time does the sun rise and set?

4. What are the sun's right ascension, declination oblique ascension, rising amplitude, oblique descension, and setting amplitude, at Petersburg, on the 21st of June; what is the ascensional difference, and what time does the sun rise and set?

5. What are the sun's right ascension, declination, oblique ascension, rising amplitude, oblique descension, and setting amplitude, at Alexandria, on the 21st

of December; what is the ascensional difference and what time does the sun rise and set?

Problem LI.

Given the day of the month and the sun's amplitude at sunrise to find the latitude of the place of observation.

Rule. Find the sun's place in the ecliptic, and bring it to the eastern or western part of the horizon, (according as the eastern or western amplitude is given,) elevate or depress the pole till the sun's place coincides with the given amplitude on the horizon, then the elevation of the pole will show the latitude.

Or, thus:

Elevate the north pole to the complement* of the amplitude, and screw the quadrant of altitude upon the brass meridian over the same degree: bring the equinoctial point Aries, to the brass meridian, and move the quadrant of altitude till the sun's declination for the given day (counted on the quadrant) coincides with the equator; the number of degrees between the point Aries, and the graduated edge of the quadrant, will be the latitude sought.

Examples. 1. The sun's amplitude at sunrise was observed to be 39° 48′ from the east towards the north, on the 21st of June; required the latitude of the place?

*The complement of the amplitude is found by subtracting the amplitude from 90°. This rule is exactly the same as above: for it is formed from a right-angled spherical triangle, the base being the complement of the amplitude, the perpendicular the latitude of the place, and the hypothenuse the complement of the sun's declination.

Answer. 51° 32′ north.*

2. The sun's amplitude was observed to be 15° 30 from the east towards the north, at the same time his declination was 15° 30′; required the latitude?

3. On the 29th of May, when the sun's declination was 21° 30′ north, his rising amplitude was known to be 22° northward of the east; required the latitude?

4. When the sun's declination was 2° north, his rising amplitude was 4° north of the east; required the latitude?

Problem LII.

Given two observed altitudes of the sun, the time elapsed between them, and the sun's declination, to find the latitude.

Rule. Find the sun's declination, either by the globe or an ephemeris; take the number of degrees contained therein from the equator with a pair of compasses, and apply the same number of degrees upon the meridian passing through Libra† from the equator northward or southward, and mark where they extend to: turn the elapsed time into degrees,‡ and count those degrees upon the equator from the meridian passing through Libra; bring that point of the equator where the reckoning ends to the graduated edge of the brass meridian, and set off the sun's declination from that

* See *Keith's Trigonometry*, fourth edition, page 285.

† Any meridian will answer the purpose as well as that which passes through Libra; on Adams' and on Cary's globes this merdian is divided like the brass meridian.

‡ See the method of turning time into degrees. Prob. XIX.

point along the edge of the meridian, the same way as before; then take the complement of the first altitude from the equator in your compasses, and, with one foot in the sun's declination, and a fine pencil in the other foot, describe an arc; take the complement of the second altitude in a similar manner from the equator, and with one foot of the compasses fixed in the second point of the sun's declination, cross the former arc: the point of intersection brought to that part of the brass meridian which is numbered from the equator towards the poles, will stand under the degree of latitude sought.

Examples. 1. Suppose on the 4th of June, 1827, in north latitude, the sun's altitude at 29 minutes past 10 in the forenoon, to be 65° 24′, and at 31 minutes past 12, 74° 8′: required the latitude?

Answer. The sun's declination is 22° 22′ north, the elapsed time two hours two min. answering to 30° 30′; the complement of the first altitude 24° 36′, the complement of the second altitude 15° 52′, and the latitude sought 36° 57′ north.

2. Given the sun's declination 19° 39′ north, his altitude in the forenoon 38° 19′, and, at the end of one hour and a half, the same morning, the altitude was 50° 25′; required the latitude of the place, supposing it to be north?

3. When the sun's declination was 22° 40′ north, his altitude at 10 h. 54 m. in the forenoon was 53° 29′, and at 1 h. 17 m. in the afternoon it was 52° 48′, required the latitude of the place of observation, supposing it to be north?

4. In north latitude, when the sun's declination was 22° 23′ south, the sun's altitude in the afternoon was

observed to be 14° 46′, and after 1 h. 22 m. had elapsed, his altitude was 8° 27′· required the latitude?

Problem LIII.

The day and hour being given when a solar eclipse will happen, to find where it will be visible.

Rule. Find the sun's declination, and elevate the pole agreeably to that declination; bring the place at which the hour is given to that part of the brass meridian which is numbered from the equator towards the poles, and set the index of the hour-circle to twelve; then, if the given time be before noon, turn the globe westward till the index has passed over as many hours as the given time wants of noon; if the time be past noon, turn the globe eastward as many hours as it is past noon, and exactly under the degree of the sun's declination on the brass meridian you will find the place on the globe where the sun will be vertically eclipsed:* at all places within 70 degrees of this place, the eclipse *may* † be visible especially if it be a total eclipse.

Example. On the 11th of February, 1804, at 27 min. past ten o'clock in the morning at London, there was an eclipse of the sun, where was it visible, sup

* The effect of parallax is so great, that an eclipse may not be visible even where the sun is vertical.

† When the moon is exactly in the node, and when the axis of the moon's shadow and penumbra pass through the centre of the earth, the breadth of the earth's surface under the penumbral shadow is 70° 20′ but the breadth of this shadow is variable; and if it be ·· accurately determined by calculation, it is impossible to tell by the globe to what extent an eclipse of the sun will be visible.

posing the moon's penumbral shadow to extend northward 70 degrees from the place where the sun was vertically eclipsed?

Answer. London, &c.

Problem LIV.

The day and hour being given when a lunar eclipse will happen, to find where it will be visible.

Rule. Find the sun's declination for the given day and note whether it be north or south; if it be north, elevate the *south* pole so many degrees above the horizon as are equal to the declination; if it be south, elevate the *north* pole in a similar manner; bring the place at which the hour is given to that part of the brass meridian which is numbered from the equator towards the poles, and set the index of the hour-circle to twelve then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; the place exactly under the degree of the sun's declination will be the antipodes of the place where the moon is vertically eclipsed, set the index of the hour-circle again to twelve, and turn the globe on its axis till the index has passed over twelve hours, then to all places above the horizon the eclipse will be visible; to those places along the western edge of the horizon, the moon will rise eclipsed; to those along the eastern edge she will set eclipsed; and to that place immediately under *the degree* of the sun's declination reckoning towards the elevated pole, the moon will be vertically eclipsed.

Example. On the 26th of January, 1804, at 58 min past seven in the afternoon at London, there was an eclipse of the moon; where was it visible?

Answer. It was visible to the whole of Europe, Africa, and the continent of Asia.

Problem LV.

To find the time of the year when the Sun or Moon will be liable to be eclipsed.

Rule 1. Find the place of the moon's nodes, the time of *new moon*, and the sun's longitude at that time by an ephemeris; then if the sun be within 17 degrees of the moon's node, there will be an eclipse of the sun.

2. Find the place of the moon's nodes, the time of full moon, and the sun's longitude at that time, by an ephemeris: then, if the sun's longitude be within 12 degrees of the moon's node, there will be an eclipse of the moon.

Or, without the ephemeris

The mean annual variation of the moon's nodes is 19° 19′ 44″ and the place of the node for the first of January 1827 being 2° 2′ in ♎, its place for any other time may therefore be found.

Examples. 1. On the 9th of June, 1827, there will be a full moon, at which time the place of the moon's node is 7° in ♎ and the sun's longitude ♉, 17° 48′; will an eclipse of the moon happen at that time?

Answer. Here the sun's longitude is not within 12 degrees of the moon's node, therefore there will be no eclipse of the moon.—When the sun is in one of the moon's nodes at the time of full moon, the moon is in the other node, and the earth is directly between them.

2. There will be a new moon on the 7th of June, 1827, at which time the place of the moon's node will be ♎, 12° 43′ and the sun's longitude ♉ 15° 54′; will there be an eclipse of the sun at that time?

3. There will be a new moon on the 18th of December 1827, at which time the place of the moon's node will be ♎ 2° 24′ and the sun's longitude ♍ 25° 51′; will there be an eclipse of the sun at that time?

4. On the 3d of November, 1827, there will be a full moon, at which time the place of the moon's node will be ♎ 4° 56′, and the sun's longitude ♎ 10° 18′; will there be an eclipse of the moon at that time?

5. On the 25th of April, 1827, there will be a new moon, at which time the place of the moon's node is ♎ 15° 19′ and the sun's longitude ♈ 4° 29′; will there be an eclipse of the sun at that time?

6. On the 20th of October, 1827, there will be a new moon, at which time the place of the moon's node is ♎ 5° 38′ and the sun's longitude ♍ 26° 19′; will there be an eclipse of the sun at that time?

Problem LVI.

To explain the phenomenon of the harvest moon.

Definition 1. The harvest moon, in north latitude is the full moon which happens at, or near the time of the autumnal equinox; for, to the inhabitants of north latitude, whenever the moon is in Pisces or Aries (and she is in these signs twelve times in a year,) there is very little difference between her times of rising for several nights together, because her orbit is at these times nearly parallel to the horizon. This peculiar rising of the moon passes unobserved at all other times of the year except in September and October; for there never can be a full moon except the sun be directly opposite to the moon; and as this particular rising of the moon can only happen when the moon is in ♓ Pisces or ♈ Aries, the sun must necessarily be either in ♍ Virgo or ♎ Libra at that time, and these signs answer to the months of September and October.

Definition 2. The harvest moon, in south latitude, is the full moon which happens at, or near, the time of the vernal equinox; for, to the inhabitants of south latitude, whenever the moon is in ♍ Virgo or ♎ Libra her orbit is nearly parallel to the horizon: but when the full moon happens in ♍ Virgo or ♎ Libra, the sun must be either in ♓ Pisces or ♈ Aries. Hence it appears that the harvest moons are just as regular in south latitude as they are in north latitude, only they happen at contrary times of the year.

Rule for performing the problem.—1. *For north latitude.* Elevate the north pole to the latitude of the place, put a patch or make a mark in the ecliptic on the point Aries, and upon every twelve degrees preceding and following that point, till there be ten or eleven marks; bring that mark which is the nearest to Pisces to the eastern edge of the horizon, and set the index to 12; turn the globe westward till the other marks successively come to the horizon, and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon will show the diurnal difference of time between the moon's rising If these marks be brought to the western edge of the horizon in the same manner, you will see the diurnal difference of time between the moon's setting: for, when there is the smallest difference between the times of the moon's rising, there will be the greatest difference between the times of her setting; and, on the contrary, when there is the greatest difference between the times of the moon's rising, there will be the least difference between the times of her setting.

NOTE. As the moon's nodes vary their position and form a complete revolution in about nineteen years, there will be a regular period of all the varieties which can happen in the rising and setting of the moon during that time. The following table (extracted from Ferguson's Astronomy,) shows in what years the harvest moons are the least and most beneficial, with regard to the times of their rising, from 1823 to 1860. The columns of years under the letter L are those in which the harvest moons are least beneficial, because they fall about the descending node; and those under M are the most beneficial, because they fall about the ascending node.

L	L	L	L	M	M	M	M
1826	1831	1845	1849	1823	1837	1842	1856
1827	1832	1846	1850	1824	1838	1843	1857
1828	1833	1847	1851	1825	1839	1853	1858
1829	1834	1848	1852	1835	1840	1854	1859
1830	1844			1836	1841	1855	1860

2. *For south latitude.* Elevate the south pole to the latitude of the place, put a patch or make a mark on the ecliptic on the point Libra, and upon every twelve degrees preceding and following that point, till there be ten or eleven marks; bring that mark which is the nearest to Virgo, to the eastern edge of the horizon, and set the index to 12; turn the globe westward

till the other marks successively come to the horizon and observe the hours passed over by the index; the intervals of time between the marks coming to the horizon will be the diurnal difference of time between the moon's rising, &c. as in the foregoing part of the problem.*

Problem LVII.

The day and hour of an eclipse of any one of the satellites of Jupiter being given, to find upon the globe all those places where it will be visible.

Rule. Find the sun's declination for the given day, and elevate the pole to that declination; bring the place at which the hour is given to the brass meridian and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe westward as many hours as it wants of noon; if after noon, turn the globe eastward as many hours as it is past noon; fix the globe in this position: Then,

1. *If Jupiter rise after the sun*,† that is, if he be an evening star, draw a line along the *eastern edge of the horizon* with a black lead pencil, this line will pass over all places on the earth where the sun is setting at the

* This solution is on a supposition that the moon keeps constantly in the ecliptic, which is sufficiently accurate for illustrating the problem. Otherwise the latitude and longitude of the moon, or her right ascension and declination, may be taken from the ephemeris, at the time of full moon, and a few days preceding and following it; her place will then be truly marked on the globe.

† Jupiter rises after the sun, when his longitude is greater than the sun's longitude.

given hour; turn the globe westward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw another line with a pencil along the eastern edge of the horizon: the eclipse will be visible to every place between these lines, viz. from the time of the sun's setting to the time of Jupiter's setting.

2. *If Jupiter rise before the sun,** that is, if he be a morning star, draw a line along the *western edge of the horizon* with a black lead pencil, this line will pass over all places of the earth where the sun is rising at the given hour; turn the globe eastward on its axis till as many degrees of the equator have passed under the brass meridian as are equal to the difference between the sun's and Jupiter's right ascension; keep the globe from revolving on its axis, and elevate the pole as many degrees above the horizon as are equal to Jupiter's declination, then draw another line with a pencil along the western edge of the horizon; the eclipse will be visible to every place between these lines, viz. from the time of Jupiter's rising to the time of the sun's rising.

Examples. 1. On the 13th of January, 1805, there was an immersion of the first satellite of Jupiter at

* Jupiter rises before the sun when his longitude is less than the sun's longitude.

9 m. 3 sec. past five o'clock in the morning at Greenwich; where was it visible?

Answer. In this example the longitude of the sun exceeds the longitude of Jupiter, therefore Jupiter was a morning star, his declination being 19° 16′ S. and his longitude 7 signs 29° 46′, by the Nautical Almanac: his right ascension and the sun's right ascension may be found by the globe; for, if Jupiter's longitude in the ecliptic be brought to the brass meridian, his place will stand under the degree of his declination;* and his right ascension will be found on the equator, reckoning from Aries. This eclipse was visible at Greenwich, the greater part of Europe, the west of Africa, Cape Verd islands, &c.

2. On the 5th of January, 1827, at 44 min. 2 sec. past seven o'clock in the morning, at Greenwich, there will be an immersion of the first satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude at that time being 6 signs 13° 41′ and his declination 4° 10′ south.

3. On the 5th of June, 1827, at 14 min. 8 sec. past eight o'clock in the evening, at Greenwich, there will be an emersion of the first satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude at that time being 6 signs 4° 31′ and his declination 0° 30′ south.

4. On the 2d of December, 1827, at 39 min. 4 sec. past six o'clock in the morning, at Greenwich, there will be an immersion of the first satellite of Jupiter; where will the eclipse be visible? Jupiter's longitude

* This is on supposition that Jupiter moves in the ecliptic, and, as he deviates but little therefrom, the solution by this method will be sufficiently accurate. To know if an eclipse of any one of the satellites of Jupiter will be visible at any place; we are directed by the Nautical Almanac to "find whether Jupiter be 8° above the horizon of the place, and the sun as much below it."

at that time being 7 signs 3° 59′ and his declination 1° 5′ north.

Problem LVIII.

To place the terrestrial globe in the SUN-SHINE, *so that it may represent the* NATURAL POSITION *of the earth.*

Rule. If you have a meridian line* drawn upon a horizontal plane, set the north and south points of the wooden horizon of the globe directly over this line; or, place the globe directly north and south by the mariner's compass, taking care to allow for the variation; bring the place in which you are situated to the brass meridian, and elevate the pole to its latitude; then the globe will correspond in every respect with the situation of the earth itself. The poles, meridians, parallel circles, tropics, and all the circles on the globe, will correspond with the same imaginary circles in the heavens; and each point, kingdom, and state, will be turned towards the real one, which it represents.

While the sun shines on the globe, one hemisphere will be enlightened, and the other will be in the shade: thus, at one view, may be seen all places on the earth which have day, and those which have night.†

If a needle be placed perpendicularly in the middle of the enlightened hemisphere, (which must of course

* As a meridian line is useful for fixing a horizontal dial, and for placing a globe directly north and south, &c. the different methods of drawing a line of this kind will precede the problems on dialling.

† For this part of the problem it would be more convenient if the globe could be properly supported without the frame of it, because the shadow of its stand, and that of its horizon, will darken several parts of the surface of the globe which would otherwise be enlightened

be upon the parallel of the sun's declination for the given day,) it will cast no shadow, which shows tha. the sun is vertical at that point; and if a line be drawn through this point from pole to pole, it will be the meridian of the place where the sun is vertical, and every place upon this line will have noon at that time; all places to the west of this line will have morning, and all places to the east of it afternoon. Those inhabitants who are situated on the circle which is the boundary between light and shade, to the westward of the meri dian where the sun is vertical, will see the sun rising those in the same circle to the eastward of this meridian will see the sun setting. Those inhabitants towards the north of the circle, which is the boundary between light and shade, will perceive the sun to the southward of them, in the horizon; and those who are in the same circle towards the south, will see the sun in a similar manner to the north of them.

If the sun shine beyond the north pole
time, his declination is as many degrees north as he shines over the pole; and all places at that distance from the pole will have constant day, till the sun's declination decreases, and those at the same distance from the south pole will have constant night.

If the sun do not shine so far as the north pole at the given time, his declination is as many degrees south as the enlightened part is distant from the pole; and all places within the shade, near the pole, will have constant night, till the sun's declination increases northward. While the globe remains steady in the position it was first placed when the sun is westward of the meridian, you may perceive on the east side of it, in what manner the sun gradually departs from place to place as the night approaches; and when the sun is eastward of the meridian, you may perceive on the western side of it, in what manner the sun advances from place to place as the day approaches.

Problem LIX.

The latitude of a place being given, to find the hour of the day at any time when the sun shines.

Rule 1. Place the north and south points of the horizon of the globe directly north and south upon a horizontal plane, by a meridian line, or by a mariner's compass, allowing for the variation, and elevate the pole to the latitude of the place; then, if the place be in north latitude, and the sun's declination be north, the sun will shine over the north pole; and if a long pin be fixed perpendicularly in the direction of the axis of the earth, and in the centre of the hour-circle, its shadow will fall upon the hour of the day, the figure XII of the hour-circle being first set to the brass meridian. If the place be in north latitude, and the sun's declination be above ten degrees south, the sun will not shine upon the hour-circle at the north pole.

Rule 2. Place the globe due north and south upon a horizontal plane, as before, and elevate the pole to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to XII; stick a needle perpendicularly in the sun's place in the ecliptic, and turn the globe on its axis till the needle casts no shadow; fix the globe in this position, and the index will show the hour before 12 in the morning, or after 12 in the afternoon.

Rule 3. Divide the equator into 24 equal parts from the point Aries, on which place the number VI; and proceed westward VII, VIII, IX, X, XI, XII, I, II, III, IV, V, VI, which will fall upon the point Libra, VII, VIII, IX, X, XI, XII, I, II, III, IV, V;* elevate the pole to the latitude, place the globe due north and south upon a horizontal plane, by a meridian line, or a good mariner's compass, allowing for the variation, and bring the point Aries to the brass meridian; then observe the circle which is the boundary between light and darkness westward of the brass meridian; and it will intersect the equator in the given hour in the morning; but, if the same circle be eastward of the brass meridian, it will intersect the equator in the given hour in the afternoon.

Or, Having placed the globe upon a true horizontal plane, set it due north and south by a meridian line; elevate the pole to the latitude, and bring the point Aries to the brass meridian, as before; then tie a small string, with a noose, round the elevated pole, stretch its other end beyond the globe, and move it so that the shadow of the string may fall upon the depressed axis; at that instant its shadow upon the equator will give the hour.†

* On *Adams'* globes the antarctic circle is thus divided, by which the problem may be solved.

† The learner must remember that the time shown in this problem is solar time, as shown by a sun-dial; and, therefore, to agree with a good clock or watch, it must be corrected by a table of equation of time See a table of this kind among the succeeding problems.

Problem LX.

To find the sun's altitude, by placing the globe in the SUN-SHINE.

Rule. Place the globe upon a truly horizontal plane, stick a needle perpendicularly over the north pole,* in the direction of the axis of the globe, and turn the pole towards the sun, so that the shadow of the needle may fall upon the middle of the brass meridian; then elevate or depress the pole till the needle casts no shadow; for then it will point directly to the sun; the elevation of the pole above the horizon will be the sun's altitude.

Problem LXI.

To find the sun's declination, his place in the ecliptic, and his azimuth, by placing the globe in the SUN-SHINE.

Rule. Place the globe upon a truly horizontal plane, in a north and south direction by a meridian line, and elevate the pole to the latitude of the place then, if the sun shine beyond the north pole, his declination is as many degrees north as he shines over the pole; if the sun do not shine so far as the north pole, his declination is as many degrees south as the enlightened part is distant from the pole. The sun's declination being found, his place may be determined by Problem XX.

* It would be an improvement on the globes were our instrument makers to drill a very small hole in the brass meridian over the north pole.

Stick a needle in the parallel of the sun's declination for the given day,* and turn the globe on its axis till the needle casts no shadow: fix the globe in this position, and screw the quadrant of altitude over the latitude; bring the graduated edge of the quadrant to coincide with the sun's place, or the point where the needle is fixed, and the degree on the horizon will show the azimuth.

CHAPTER III.

PROBLEMS PERFORMED WITH THE CELESTIAL GLOBE.

Problem LXII.

To find the right ascension and declination of the sun, or a star.

Rule. Bring the sun or star to that part of the brass meridian which is numbered from the equinoctial towards the poles; the degree on the brass meridian is the declination, and the number of degrees on the equinoctial, between the brass meridian and the point Aries, is the right ascension.

Or. Place both the poles of the globe in the horizon, bring the sun or star to the eastern part of the horizon; then the number of degrees which the sun or star is northward or southward of the east, will be the declination north or south; and the degrees on the equinoc-

* On *Adams'* globes the torrid zone is divided into degrees by dotted lines, so that the parallel of the sun's declination is instantly found: in using other globes, observe the declination on the brass meridian, and stick a needle perpendicularly in the globe under that degree.

tial, from Aries to the horizon, will be the right ascension

EXAMPLES. 1. Required the right ascension and declination of α Dubhe, in the back of the Great Bear.

Answer. Right ascension 162° 49′, declination 62° 48′ N.

2. Required the right ascensions and declinations of the following stars?

γ, *Algenib*, in Pegasus.
α, *Scheder*, in Cassiopeia.
β, *Mirach*, in Andromeda.
α, *Acherner*, in Eridanus.
α, *Menkar*, in Cetus.
β, *Algol*, in Perseus.
α, *Aldebaran*, in Taurus.
α, *Capella*, in Auriga.
β, *Rigel*, in Orion.
γ, *Bellatrix*, in Orion.
α, *Betelgeux*, in Orion.
α, *Canopus*, in Argo Navis.
α, *Procyon*, in the Little Dog.
γ, *Algorab*, in the Crow.
α, *Arcturus*, in Boötes.
ε, *Vendemiatrix*, in Virgo.

PROBLEM LXIII.

*To find the latitude and longitude of a star.**

RULE. Place the upper end of the quadrant of altitude on the north or south pole of the ecliptic, according as the star is on the north or south side of the ecliptic, and move the other end till the star comes to the graduated edge of the quadrant: the number of degrees between the ecliptic and the star is the latitude; and the number of degrees on the ecliptic, reckoned eastward from the point Aries to the quadrant, is the longitude.

OR, Elevate the north or south pole 66½° above the horizon, according as the given star is on the north or

* The latitudes and longitudes of the planets must be found from an ephemeris.

south side of the ecliptic; bring the pole of the eclip tic to that part of the brass meridian which is number ed from the equinoctial towards the pole: then the ecliptic will coincide with the horizon; screw the quadrant of altitude upon the brass meridian over the pole of the ecliptic; keep the globe from revolving on its axis, and move the quadrant till its graduated edge comes over the given star: the degree on the quadrant cut by the star is its latitude; and the sign and degree on the ecliptic cut by the quadrant show its longitude.

EXAMPLES. 1. Required the latitude and longitude of α *Aldebaran* in Taurus?

Answer. Latitude 5° 28′ S. longitude 2 signs 6° 53′; or 6° 53′ in Gemini.

2. Required the latitudes and longitudes of the following stars?

α, *Markab*, in Pegasus.
β, *Scheat*, in Pegasus.
α, *Fomalhaut*, in the S. Fish.
α, *Deneb*, in Cygnus.
α, *Altair*, in the Eagle.
β, *Albireo*, in Cygnus.
α, *Vega*, in Lyra.
γ, *Rastaben*, in Draco.
α, *Antares*, in the Scorpion.
α, *Arcturus*, in Boötes.
β, *Pollux*, in Gemini.
β, *Rigel*, in Orion.

PROBLEM LXIV.

The right ascension and declination of a star, the moon, a planet, or of a comet, being given, to find its place on the globe.

RULE. Bring the given degrees of right ascension to that part of the brass meridian which is numbered from the equinoctial towards the poles: then under the given declination on the brass meridian you will find the star, or place of the planet.

EXAMPLES. 1. What star has 261° 29′ of right ascension, and 52° 27′ north declination?

Answer. β in Draco.

2. On the 31st of January, 1825, the moon's right ascension was 91° 21′, and her declination 23° 19′; find her place on the globe at that time.

Answer. In the milky way, a little above the left foot of Castor.

3. What stars have the following right ascensions and declinations?

Right Ascensions.	Declinations.	Right Ascensions.	Declinations.
7° 19′	55° 26′ N.	83° 6′	34° 11′ S.
11 11	59 38 N.	86 13	44 55 N.
25 54	19 50 N.	99 5	16 26 S.
46 32	9 34 S.	110 27	32 19 N.
53 54	23 29 N.	113 16	28 30 N.
76 14	8 27 S.	129 2	7 8 N.

4. On the 1st of December, 1827, the moon's right ascension at midnight will be 50° 58′, and her declination 16° 58′ N.; find her place on the globe.

5. On the 1st of May, 1827, the declination of Venus will be 1° 11′ S. and her right ascension 0° 4′, find her place on the globe at that time.

6. On the 19th of January, 1827, the declination of Jupiter will be 4° 21′ S. and his right ascension 12° 55′; find his place on the globe at that time.

Problem LXV.

The latitude and longitude of the moon, a star or a planet, given, to find its place on the globe.

Rule. Place the division of the quadrant of altitude marked 0, on the given longitude in the ecliptic, and the upper end on the pole of the ecliptic ; then, under the given latitude, on the graduated edge of the quadrant, you will find the star, or place of the moon or planet.

Examples. 1. What star has 0 signs 6° 16′ of longitude, and 12° 36′ N. latitude?

Answer. γ in Pegasus.

2. On the 5th of June, 1827, at midnight, the moon's longitude will be 6ˢ 23° 41′; and her latitude 1° 49 S.; find her place on the globe.

3. What stars have the following latitudes and longitudes?

Latitudes.	Longitudes.	Latitudes.	Longitudes.
12° 35′ S.	1ˢ 11° 25′	39° 33′ S.	3ˢ 11° 13′
5 29 S.	2 6 53	10 4 N.	3 17 21
31 8 S.	2 13 56	0 27 N.	4 26 57
22 52 N.	2 18 57	44 20 N.	7 9 22
16 3 S.	2 25 51	21 6 S.	11 0 56

4. On the first of June, 1827, the longitudes and latitudes of the planets will be as follow : required their places on the globe?

Longitudes.	Latitudes.	Longitudes.	Latitudes.
☿ 2ˢ 0° 54′	0° 29′ S.	♃ 6ˢ 4° 28′	1° 27′ N.
♀ 1 7 1	1 52 S.	♄ 3 5 47	0 32 S.
♂ 2 22 12	0 46 N.	♅ 9 27 52	21 5 S

PROBLEM LXVI.

The day and hour, and the latitude of a place being given, to find what stars are rising, setting, culminating, &c.

RULE. Elevate the pole to the latitude of the place find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12: then, if the time be before noon, turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon; but, if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: then all the stars on the eastern semi-circle of the horizon will be rising, those on the western semi-circle will be setting, those under the brass meridian above the horizon will be culminating, those above the horizon will be visible at the given time and place, those below will be invisible.

If the globe be turned on its axis from east to west, those stars which do not go below the horizon never set at the given place; and those which do not come above the horizon never rise; or, if the given latitude be subtracted from 90 degrees, and circles be described on the globe, parallel to the equinoctial, at a distance from it equal to the degrees in the remainder, they will be the circles of perpetual apparition and occultation.

EXAMPLES. 1. On the 9th of February, when it is nine o'clock in the evening at London, what stars are rising, what stars are setting, and what stars are on the meridian?

Answer. Alphacca, in the northern Crown is rising; Arcturus and Mirach, in Boötes, just above the horizon; Sirius on the meridian; Procyon and Castor and Pollux a little east of the meridian. The constellations Orion, Taurus, and Auriga, a little west of the meridian: Markab, in Pegasus, just below the western edge of the horizon, &c.

2. On the 20th of January, at two o'clock in the morning at London, what stars are rising, what stars are setting, and what stars are on the meridian?

Answer. Vega in Lyra, the head of the Serpent, Spica Virginis, &c. are rising; the head of the Great Bear, the claws of Cancer, &c. on the meridian; the head of Andromeda, the neck of Cetus, and the body of Columba Noachi, &c. are setting.

3. At ten o'clock in the evening at Edinburgh, on the 15th of November, what stars are rising, what stars are setting, and what stars are on the meridian?

4. What stars do not set in the latitude of London, and at what distance from the equinoctial is the circle of perpetual apparition?

5. What stars do not rise to the inhabitants of Edinburgh, and at what distance from the equinoctial is the circle of perpetual occultation?

6. What stars never rise at Otaheite, and what stars never set at Jamaica?

7. How far must a person travel southward from London to lose sight of the Great Bear?

8. What stars are continually above the horizon at the north pole, and what stars are constantly below the horizon thereof?

Problem LXVII.

The latitude of a place, day of the month, and hour being given, to place the globe in such a manner as to represent the heavens at that time; in order to find out the relative situations and names of the constellations and remarkable stars.

Rule. Take the globe out into the open air, on a clear star-light night, where the surrounding horizon is uninterrupted by different objects; elevate the pole to the latitude of the place, and set the globe due north and south by a meridian line, or by a mariner's compass, taking care to make a proper allowance for the variation; find the sun's place in the ecliptic, bring it to the brass meridian and set the index of the hour-circle to 12; then, if the time be after noon, turn the globe westward on its axis, till the index has passed over as many hours as the time is past noon; but, if the time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; fix the globe in this position, then the flat end of a pencil being placed on any star on the globe so as to point towards the centre, the other end will point to that particular star in the heavens.

Problem LXVIII.

To find when any star, or planet, will rise, come to the meridian, and set at any given place.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12. Then if the star or planet be *below* the horizon, turn the globe *westward* till the star or planet comes to the eastern part of the horizon, the hours passed over by the index will show the time from noon when it rises; and, by continuing the motion of the globe westward till the star, &c. comes to the meridian, and to the western part of the horizon successively, the hours passed over by the index will show the time of culminating and setting.

If the star, &c. be *above* the horizon and *east* of the meridian, find the time of culminating, setting, and rising, in a similar manner. If the star, &c. be *above* the horizon *west* of the meridian, find the time of setting, rising, and culminating, by turning the globe westward on its axis.

Examples. 1. At what time will Arcturus rise, come to the meridian, and set, at London, on the 7th of September?

Answer. It will rise at seven o'clock in the morning, come to the meridian at three in the afternoon, and set at eleven o'clock at night.

2. On the 1st of August, 1805, the longitude of Jupiter was 7 signs 26 deg. 34 min., and his latitude 45 min. N.; at what time did he rise, culminate, and set, at Greenwich, and whether was he a morning or an evening star?

Answer. Jupiter rose at half past two in the afternoon, came to the meridian at about ten minutes to seven, and set at a quarter past eleven in the evening. Here Jupiter was an evening star, because he set after the sun.

3. At what time does Sirius rise, set, and come to the meridian of London, on the 31st of January?

4. On the 1st of January, 1827, the longitude of Venus will be 8 signs 27 deg. 10 min. and her latitude 1 deg. 29 min. N.; at what time will she rise, culminate, and set at Paris, and whether will she be a morning or an evening star?

5. At what time does Aldebaran rise, come to the meridian, and set at Dublin, on the 25th of November?

6. On the first of February, 1827, the longitude of Mars will be 11 signs 26 deg. 26 min., and latitude 0 deg. 32 min. S.; at what time will he rise, set, and come to the meridian of Greenwich?

Problem LXIX.

To find the amplitude of any star, its oblique ascension and descension, and its diurnal arc for any given day.

Rule. Elevate the pole to the latitude of the place, and bring the given star to the eastern part of the horizon; then the number of degrees between the star and the eastern point of the horizon will be its rising amplitude; and the degree of the equinoctial cut by the horizon will be the oblique ascension: set the index of the hour-circle to 12, and turn the globe westward till the given star comes to the western edge of the horizon; the hours passed over by the index will be the star's diurnal arc, or continuance above the horizon. The setting amplitude will be the number of degrees between the star and the western point of the horizon, and the oblique descension will be represented by that degree of the equinoctial which is intersected by the horizon, reckoning from the point Aries.

EXAMPLES. 1. Required the rising and setting amplitude of Sirius, its oblique ascension, oblique descension, and diurnal arc, at London?

Answer. The rising amplitude is 27 deg. to the south of the east setting amplitude 27 deg. south of the west; oblique ascension 120 deg; oblique descension 77 deg.; and diurnal arc 9 hours 6 minutes.

2. Required the rising and setting amplitude of Aldebaran, its oblique ascension, oblique descension, and diurnal arc, at London?

3. Required the rising and setting amplitude of Arcturus, its oblique ascension, oblique descension, and diurnal arc, at London?

4. Required the rising and setting amplitude of γ Bellatrix, its oblique ascension, oblique descension, and diurnal arc, at London?

PROBLEM LXX.

To find the distances of the stars from each other in degrees.

RULE. Lay the quadrant of altitude over any two stars, so that the division marked o may be on one of the stars; the degrees between them will show their distance, or the angle which these stars subtend, as seen by a spectator on the earth.

EXAMPLES. 1. What is the distance between Vega in Lyra, and Altair in the Eagle?

Answer. 34 degrees.

2. Required the distance between β in the Bull's Horn and γ Bellatrix in Orion's shoulder?

3. What is the distance between β in Pollux, and α in Procyon?

4. What is the distance between η, the brightest of the Pleiades, and β in the Great Dog's Foot?

5. What is the distance between ε in Orion's girdle and ζ in Cetus?

6. What is the distance between Arcturus in Boötes, and β in the right shoulder of Serpentarius?

Problem LXXI.

To find what stars lie in or near the moon's path, or what stars the moon can eclipse, or make a near approach to.

Rule. Find the moon's longitude and latitude, or her right ascension and declination, in an ephemeris, for several days, and mark the moon's places on the globe; then by laying a thread, or the quadrant of altitude, over these places, you will see nearly the moon's path, and consequently, what stars lie in her way.

Examples. 1. What stars were in, or near, the moon's path, on the 10th, 11th, 13th, and 16th of December, 1805?

10th,	☽'s longitude	♌ 20°	12′	latitude	3°	34′	S.
11th,	- -	♍ 4	22	- -	4	25	S.
13th,	- -	♎ 1	39	- -	5	15	S.
16th,	- -	♏ 10	11	- -	4	26	S

Answer. The stars will be found to be Cor Leonis or Regulus, Spica Virginis, α in Libra, &c. See page 47, White's Ephemeris.

2. On the 1st, 2d, 3d, 4th, and 5th of April, 1827 what stars will lie near the moon's way?

1st, ☽'s right ascension,	72° 6'	declination	19° 55' N
2d, - -	84 41	- -	19 59 N.
3d, - -	97 14	- -	19 9 N.
4th, -	109 44	- -	17 28 N
5th, - -	122 8	- -	14 58 N

Problem LXXII.

Given the latitude of the place and the day of the month, to find what planets will be above the horizon after sun-setting.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, and bring it to the western part of the horizon, or to ten or twelve degrees below; then look in the ephemeris for that day and month, and you will find what planets are above the horizon, such planets will be fit for observation on that night.

Examples. 1. Were any of the planets visible after the sun had descended ten degrees below the horizon of London, on the 1st of December, 1805? Their longitudes being as follow:

☿	8ˢ 22° 30'	♃	8ˢ 15° 27'	☽'s longitude at
♀	9 23 40	♄	6 24 50	midnight 0ˢ 9°
♂	8 25 21	♅	6 24 5	

Answer. Venus and the moon were visible.

2. What planets will be above the horizon of London when the sun has descended ten degrees below, on the 1st of January, 1827? Their longitudes being as follow:

☿ 8 17° 51′	♃ 6ˢ 12° 13	☽'s longitude at
♀ 8 27 10	♄ 3 2 1	midnight 11ˢ 5° 9′
♂ 11 2 48	♅ 9 23 22	

Problem LXXIII.

Given the latitude of the place, day of the month, and hour of the night or morning, to find what planets will be visible at that hour.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but if the given time be past noon, turn the globe westward on its axis till the index has passed over as many hours as the time is past noon: let the globe rest in this position, and look in the ephemeris for the longitudes of the planets, and, if any of them be in the signs which are above the horizon, such planets will be visible.

Examples. 1. On the 1st of December, 1805, the longitudes of the planets, by an ephemeris, were as follow; were any of them visible at London at five o'clock in the morning?

☿ 8ˢ 22° 30′	♃ 8ˢ 15° 27′	☽'s longitude at
♀ 9 23 40	♄ 6 24 50	midnight 0ˢ 9° 15′.
♂ 8 25 21	♅ 6 24 5	

Answer. Saturn and the Georgium Sidus were visible, and both nearly in the same point of the heavens, near the eastern horizon, Saturn was a little to the north of the Georgian

2. On the first of June, 1827, the longitudes of the planets in the fourth page of the Nautical Almanac are as follow: will any of them be visible at London at ten o'clock in the evening?

☿	2^s	0°	54′	♃	6^s	4°	28′	☽'s longitude at
♀	1	7	1	♄	3	5	47	midnight 5^s 0° 25′.
♂	2	22	12	♅	9	27	52	

Problem LXXIV.

The latitude of the place and day of the month being given, to find how long Venus rises before the sun when she is a morning star, and how long she sets after the sun when she is an evening star.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place; find the latitude and longitude of Venus in an ephemeris, and mark her place on the globe; find the sun's place in the ecliptic, and bring it to the brass meridian; then, if the place of Venus be to the right hand of the meridian, she is an evening star; if to the left hand she is a morning star.

When Venus is an evening star. Bring the sun's place to the western edge of the horizon, and set the index of the hour-circle to 12; turn the globe westward on its axis till Venus coincides with the western edge of the horizon; and the hours passed over by the index will show how long Venus sets after the sun.

When Venus is a morning star. Bring the sun's place to the eastern edge of the horizon, and set the index of the hour-circle to 12; turn the globe eastward on its axis till Venus comes to the eastern edge of the horizon, and the hours passed over by the index will show how long Venus rises before the sun.

NOTE. *The same rule will serve for Jupiter, by marking his place instead of that of Venus.*

EXAMPLES. 1. On the first of March, 1805, the longitude of Venus was 10 signs, 18 deg. 14 min., or 18 deg. 14 min. in Aquarius, latitude 0 deg. 52 min. south: was she a morning or an evening star? If a morning star, how long did she rise before the sun at London; if an evening star how long did she shine after the sun set?

Answer. Venus was a morning star, and rose three quarters of an hour before the sun.

2. On the 25th of October, 1805, the longitude of Jupiter was 8 signs 7 deg. 26 min., or 7 deg. 26 min. in Sagittarius, latitude 0 deg. 29 min. north: whether was he a morning or an evening star? If a morning star, how long did he rise before the sun at London? If an evening star, how long did he shine after the sun set?

Answer. Jupiter was an evening star, and set 1 hour and 20 min. after the sun.

3. On the 1st of January, 1827, the longitude of Venus will be 8 signs 27 deg. 10 min., latitude 4 deg. 29 min. north: will she be a morning or an evening star? If she be a morning star, how long will she rise before the sun at London? If an evening star, how long will she shine after the sun sets?

4. On the seventh of July, 1827, the longitude of Jupiter will be 6 signs 5 deg. 46 min., latitude 1 deg. 19 min north; will he be a morning or an evening

star? If he be a morning star, how long will he rise before the sun? If an evening star, how long will he shine after the sun sets?

Problem LXXV.

The latitude of a place and day of the month being given to find the meridian altitude of any star or planet.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; then,

For a star. Bring the given star to that part of the brass meridian, which is numbered from the equinoctial towards the poles; the degrees on the meridian contained between the star and the horizon will be the altitude required.

For the moon or a planet. Look in an ephemeris for the planet's latitude and longitude, or for its right ascension and declination, for the given month and day, and mark its place on the globe; bring the planet's place to the brass meridian; and the number of degrees between that place and the horizon will be the altitude.

Examples. 1. What is the meridian altitude of Aldebaran in Taurus, at London?

Answer. 54° 36′.

2. What is the meridian altitude of Arcturus in Boötes, at London?

3. On the first of February, 1827, the longitude of Jupiter will be 6 signs 14 deg. 25 min., and latitude 1 deg. 27 min. north: what will his meridian altitude be at London?

4. On the first of November, 1827, the longitude of

Saturn will be 3 signs 20 deg. 18 min. and latitude 0 deg. 21 min. south: what will his meridian altitude be at London?

5 On the first of April, 1827, at the time of the moon's passage over the meridian of Greenwich, her right ascension is 67° 49′, and declination 19° 40′ N. required her meridian altitude at Greenwich?

6. On the 21st of December, 1827, the moon will pass over the meridian of Greenwich at 56 minutes past two o'clock in the evening; required her meridian altitude?

The ☽'s right ascension at noon being	44° 49′,	declination 15° 51′ N.
Do. at midnight - - - - - -	50 58	- - - 16 58 N.

Problem LXXVI.

To find all those places on the earth to which the moon will be nearly vertical on any given day.

Rule. Look in an ephemeris for the moon's latitude and longitude for the given day, and mark her place on the globe (as in Prob. LXV.); bring this place to that part of the brass meridian which is numbered from the equinoctial towards the poles, and observe the degree above it; for all places on the earth having that latitude will have the moon vertical (or nearly so) when she comes to their respective meridians.

Or: Take the moon's declination from page VI. of the Nautical Almanac, and mark whether it be north or south, then, by the terrestrial globe, or by a map, find all places having the same number of degrees of latitude as are contained in the moon's declination and those will be the places to which the moon will be successively vertical on the given day. If the moon's declination be north, the places will be in north latitude; if the moon's declination be south, they will be in south latitude.

Examples. 1. On the 15th of October, 1805, the moon's longitude at midnight was 3 signs 29 deg. 14 min., and her latitude 1 deg. 35 min. south; over what places did she pass nearly vertical?

Answer. From the moon's latitude and longitude being given, her declination may be found by the globe to be about 19° north. The moon was vertical at Porto Rico, St. Domingo, the north of Jamaica, O'why'hee, &c.

2. On the 9th of September, 1827, the moon's longitude at midnight will be 1 sign 10 deg., and her latitude 0 deg. 22 min. south; over what places on the earth will she pass nearly vertical?

3. What is the greatest north declination which the moon can possibly have, and to what places will she be then vertical?

4. What is the greatest south declination which the moon can possibly have, and to what places will she be then vertical?

Problem LXXVII.

Given the latitude of a place, day of the month, and the altitude of a star, to find the hour of the night, and the star's azimuth.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude: find the sun's place in the ecliptic bring it to the brass meridian, and set the index of the hour-circle to 12 ; bring the lower end of the quadrant of altitude to that side of the meridian on which the star was situated when observed ; turn the globe *westward* till the centre of the star cuts the given altitude on the quadrant ; count the hours which the index has passed over, and they will show the time from noon when the star has the given altitude : the quadrant will intersect the horizon in the required azimuth.

EXAMPLES. 1. At London, on the 28th of December, the star Deneb in the Lion's tail, marked β, was observed to be 40 deg. above the horizon, and east of the meridian : what hour was it, and what was the star's azimuth ?

Answer. By bringing the sun's place to the meridian, and turning the globe westward on its axis till the star cuts 40 deg. of the quadrant *east of the meridian,* the index will have passed over 14 hours ; consequently, the star has 40 deg. of altitude east of the meridian, 14 hours from noon, or at two o'clock in the morning. Its azimuth will be 62½ deg. from the south towards the east.

2. At London, on the 28th of December, the star β, in the Lion's tail, was observed to be westward of the meridian, and to have 40 deg. of altitude : what hour was it, and what was the star's azimuth ?

Answer. By turning the globe westward on its axis till the star cuts 40 deg. of the quadrant *west of the meridian,* the index will have passed over 20 hours ; consequently, the star has 40 deg. of altitude west of the meridian, 20 hours from noon, or at eight o'clock in the morning. Its azimuth will be 62½ deg. from the south towards the west.

3. At London, on the 1st of September, the altitude of Benetnach in Ursa Major, marked η, was observed to be 36 degrees above the horizon, and west of the meridian ; what hour was it, and what was the star's azimuth ?

4. On the 21st of December, the altitude of Sirius, when west of the meridian at London, was observed to be 8 deg. above the horizon; what hour was it, and what was the star's azimuth?

5. On the 12th of August, Menkar in the Whale's jaw, marked α, was observed to be 37 deg. above the horizon of London, and eastward of the meridian; what hour was it, and what was the star's azimuth?

Problem LXXVIII.

Given the latitude of a place, day of the month, and hour of the day, to find the altitude of any star, and its azimuth.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon; turn the globe eastward on its axis till the index has passed over as many hours as the time wants of noon; if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon: let the globe rest in this position, and move the quadrant of altitude till its graduated edge coincides with the centre of the given star; the degrees on the quadrant, from the horizon to the star, will be the altitude; and the distance from the north or south point of the horizon to the quadrant, counted on the horizon, will be the azimuth from the north or south.

Examples. 1. What are the altitude and azimuth of Capella at Rome, when it is five o'clock in the morning on the 2d of December?

Answer. The altitude is 41 deg. 58 min. and the azimuth 60 deg. 50 min. from the north towards the west.

2. Required the altitude and azimuth of Altair in Aquila on the 6th of October, at nine o'clock in the evening, at London?

3. On what point of the compass does the star Aldebaran bear at the Cape of Good Hope, on the 5th of March, at a quarter past eight o'clock in the evening; and what is its altitude?

4. Required the altitude and azimuth of Acyone in the Pleiades marked η, on the 21st of December, at four o'clock in the morning, at London

Problem LXXIX.

Given the latitude of the place, day of the month, and azimuth of a star, to find the hour of the night and the star's altitude.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to twelve; bring the lower end of the quadrant of altitude to coincide with the given azimuth on the horizon, and hold it in that position; turn the globe westward till the given star comes to the graduated edge of the quadrant, and the hours passed over by the index will be the time from noon; the degrees on the quadrant, reckoning from the horizon to the star, will be the altitude.

Examples. 1. At London, on the 28th of December, the azimuth of Deneb in the Lion's tail marked β, was 62½ deg. from the south towards the west; what hour was it, and what was the star's altitude?

Answer. By turning the globe westward on its axis, the index will pass over 20 hours before the star intersects the quadrant; therefore the time will be 20 hours from noon, or eight o'clock in the morning; and the star's altitude will be 40 deg.

2. At London, on the 5th of May, the azimuth of Cor Leonis, or Regulus, marked α, was 74 deg. from the south towards the west; required the star's altitude, and the hour of the night?

3. On the 8th of October, the azimuth of the star marked β, in the shoulder of Auriga, was 50 deg. from the north towards the east; required its altitude at London, and the hour of the night?

4. On the 10th of September, the azimuth of the star marked ε, in the Dolphin, was 20 deg. from the south towards the east; required its altitude at London, and the hour of the night?

Problem LXXX.

Two stars being given, the one on the meridian, and the other on the east or west part of the horizon, to find the latitude of the place.

Rule. Bring the star which was observed to be on the meridian, to the brass meridian; keep the globe from turning on its axis, and elevate or depress the pole till the other star comes to the eastern or western part of the horizon; then the degrees from the elevated pole to the horizon will be the latitude.

Examples. 1. When the two pointers of the Great Bear, marked α and β, or Dubhe and β, were on the meridian, I observed Vega in Lyra to be rising; required the latitude?

Answer. 27 deg. north.

2. When Arcturus in Boötes was on the meridian, Altair in the Eagle was rising; required the latitude?

3. When the star marked β in Gemini was on the meridian, ε in the shoulder of Andromeda was setting; required the latitude?

4. In what latitude are α and β, or Sirius and β in Canis Major rising, when Algenib, or α, in Perseus, is on the meridian?

Problem LXXXI.

The latitude of the place, the day of the month, and two stars that have the same azimuth, being given, to find the hour of the night.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; turn the globe on its axis from east to west till the two given stars coincide with the graduated edge of the quadrant of altitude; the hours passed over by the index will show the time from noon, and the common azimuth of the two stars will be found on the horizon.

Examples. 1. At what hour at London, on the 1st of May, will Altair in the Eagle, and Vega in the Harp, have the same azimuth, and what will that azimuth be?

Answer. By bringing the sun's place to the meridian, &c. and turning the globe westward, the index will pass over 15 hours before the stars coincide with the quadrant; hence they will have the same azimuth at 15 hours from noon, or at three o'clock in the morning; and the azimuth will be 42½ deg. from the south towards the east

2. On the 10th of September, what is the hour at London, when Deneb in Cygnus, and Markab in Pegasus, have the same azimuth, and what is the azimuth?

3. At what hour on the 15th of April will Arcturus and Spica Virginis have the same azimuth at London, and what will that azimuth be?

4. On the 20th of February, what is the hour at Edinburgh when Capella and the Pleiades have the same azimuth, and what is the azimuth?

5. On the 21st of December, what is the hour at Dublin when α or Algenib in Perseus, and β in the Bull's horn, have the same azimuth, and what is the azimuth?

Problem LXXXII.

The latitude of the place, the day of the month, and two stars that have the same altitude, being given, to find the hour of the night.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; turn the globe on its axis from east to west till the two given stars coincide with the given altitude on the graduated edge of the quadrant; the hours passed over by the index will be the time from noon when the two stars have that altitude.

Examples. 1. At what hour at London, on the 2d of September, will Markab in Pegasus, and α in the head of Andromeda, have each 30 deg. of altitude?

Answer. At a quarter past eight in the evening.

2. At what hour at London, on the 5th of January, will α, Menkar, in the Whale's jaw, and α, Aldebaran, in Taurus, have each 35 deg. of altitude?

3. At what hour at Edinburgh, on the 10th of November, will α, Altair, in the body of the Eagle, and ζ, in the tail of the Eagle, have each 35 deg. of altitude?

4. At what hour at Dublin, on the 15th of May, will η, Benetnach, in the Great Bear's tail, and γ, in the shoulder of Boötes, have 56 deg. of altitude?

Problem LXXXIII.

The altitudes of two stars having the same azimuth, and that azimuth being given, to find the latitude of the place.

Rule. Place the graduated edge of the quadrant of altitude over the two stars, so that each star may be exactly under its given altitude on the quadrant; hold the quadrant in this position, and elevate or depress the pole till the division marked o, on the lower end of the quadrant, coincides with the given azimuth on the horizon: when this is effected, the elevation of the pole will be the latitude.

Examples. 1. The altitude of Arcturus was observed to be 40 deg. and that of Cor. Caroli 68 deg. their common azimuth at the same time was 71 deg. from the south towards the east; required the latitude?

Answer. 51½ deg. north.

2. The altitude of ε in Castor was observed to be 40 deg., and that of β in Procyon 20 deg.; their common azimuth at the same time was 73½ deg. from the south towards the east; required the latitude?

3. The altitude of α, Dubhe, was observed to be 40 deg., and that of γ in the back of the Great Bear 29½ deg., their common azimuth at the same time was 30 deg. from the north towards the east; required the latitude?

4. The altitude of Vega, or α in Lyra, was observed to be 70 deg., and that of α in the head of Hercules 39½ deg., their common azimuth at the same time was 60 deg. from the south towards the west; required the latitude?

Problem LXXXIV.

The day of the month being given, and the hour when any known star rises or sets, to find the latitude of the place.

Rule. Find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon; elevate or depress the pole till the centre of the given star coincides with the horizon; then the elevation of the pole will show the latitude.

EXAMPLES. 1. In what latitude does ε, Mirach, in Boötes, rise at half past twelve o'clock at night, on the tenth of December?

Answer. 51½ deg. north.

2. In what latitude does Cor Leonis, or Regulus, rise at ten o'clock at night, on the 21st of January?

3. In what latitude does β, Rigel in Orion, set at four o'clock in the morning, on the 21st of December?

4. In what latitude does β, Capricornus, set at eleven o'clock at night, on the 10th of October?

PROBLEM LXXXV.

To find on what day of the year any given star passes the meridian at any given hour.

RULE. Bring the given star to the brass meridian, and set the index to 12; then, if the given time be before noon, turn the globe westward till the index has passed over as many hours as the time wants of noon, but, if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon; observe that degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto, on the horizon, will be the day required.

EXAMPLES. 1. On what day of the month does Procyon come to the meridian of London at three o'clock in the morning?

Answer. Here the time is nine hours before noon, the globe must therefore be turned nine hours towards the west, the point of the ecliptic intersected by the brass meridian will then be the ninth of ♐, answering nearly to the first of December.

2. On what day of the month, and in what month does α, Alderamin, in Cepheus, come to the meridian of Edinburgh at ten o'clock at night?

Answer. Here the time is ten hours after noon; the globe must therefore be turned ten hours towards the east, the point of the ecliptic intersected by the brass meridian will then be the 17th of ♍, answering to the ninth of September.

3. On what day of the month, and in what month does β, Deneb, in the Lion's tail, come to the meridian of Dublin at nine o'clock at night?

4. On what day of the month, and in what month, does Arcturus in Boötes come to the meridian of London at noon?

5. On what day of the month, and in what month, does δ in the Great Bear come to the meridian of London at midnight?

6. On what day of the month, and in what month, does Aldebaran come to the meridian of Philadelphia at five o'clock in the morning at London?

Problem LXXXVI.

The day of the month being given, to find at what hour any given star comes to the meridian.

Rule. Find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; turn the globe westward on its axis till the given star comes to the brass meridian, and the hours passed over by the index will be the time from noon when the star culminates.

OR, WITHOUT THE GLOBE.

Subtract the right ascension of the sun for the given day from the right ascension of the star, and the remainder will be the time of the star's culminating *nearly*. If the sun's right ascension exceeds the star's add 24 hours to the star's before you subtract.

EXAMPLES. 1. At what hour does Cor Leonis, or Regulus, come to the meridian of London on the 23d of September?

Answer. The index will pass over 21¾ hours; hence this star culminates or comes to the meridian 21¾ hours after noon, or at three quarters past nine o'clock in the morning.

2. At what hour does Arcturus come to the meridian of London on the 9th of February?

Answer. The index will pass over 16½ hours; hence Arcturus culminates 16½ hours after noon, or at half past four o'clock in the morning.

3. Required the hours at which the following stars come to the meridian of London on the respective days annexed:

Bellatrix, January 9th.	β Mirach, October 5th.
Menkar, May 18th.	Aldebaran, Feb. 12th.
γ Draco, Sept. 22d.	β Aries, November 5th.
α Dubhe, Dec. 20th.	γ Taurus, January 24th

4. At what time will Sirius come to the meridian of Greenwich on the 18th of December, 1827, his right ascension being 99° 15′ 26″, and the sun's right ascension 265° 29′ 0″.

Problem LXXXVII.

Given the azimuth of a known star, the latitude, and the hour, to find the star's altitude and the day of the month.

Rule. Bring the pole so many degrees above the horizon as are equal to the latitude of the given place, screw the quadrant of altitude upon the brass meridian over that latitude, bring the division marked o on the lower end of the quadrant to the given azimuth on the horizon, turn the globe till the star coincides with the graduated edge of the quadrant, and set the index of the hour-circle to 12; then if the given time be before noon, turn the globe westward till the index has passed over as many hours as the time wants of noon; if the given time be past noon, turn the globe eastward till the index has passed over as many hours as the time is past noon; observe that degree of the ecliptic which is intersected by the graduated edge of the brass meridian, and the day of the month answering thereto, on the horizon, will be the day required.

Examples. 1. At London, at ten o'clock at night, the azimuth of Spica Virginis was observed to be 40 deg. from the south towards the west; required its altitude, and the day of the month?

Answer. The star's altitude is 20 deg. and the day is the 18th of June. The time being ten hours past noon, the globe must be turned ten hours towards the east.

2. At London, at four o'clock in the morning, the

azimuth of Arcturus was 70 deg. from the south towards the west; required its altitude, and the day of the month?

Answer. Here the time wants eight hours of noon, therefore the globe must be turned eight hours westward; the altitude of the star will be found to be 40 deg., and the day the 12th of April.

3. At Edinburgh, at 11 o'clock at night, the azimuth of α Serpentarius, or Ras Alhagus, was 60 deg. from the south towards the east; required its altitude, and the day of the month?

4. At Dublin, at two o'clock in the morning, the azimuth of β Pegasus, or Scheat, was 70 deg. from the north towards the east; required its altitude, and the day of the month?

Problem LXXXVIII.

The altitudes of two stars being given, to find the latitude of the place.

Rule. Subtract each star's altitude from 90 degrees; take successively the extent of the number of degrees, contained in each of the remainders, from the equinoctial, with a pair of compasses; with the compasses thus extended, place one foot successively in the centre of each star, and describe arcs on the globe with a black-lead pencil; these arcs will cross each other in the zenith; bring the point of intersection to that part of the brass meridian which is numbered from the equinoctial towards the poles, and the degree above it will be the latitude.

Examples. 1. At sea, in north latitude, I observed the altitude of Capella to be 30 deg., and that of Aldebaran 35 deg.; what latitude was I in?

Answer. With an extent of 60 deg. (=90°—30°) taken from the equinoctial, and one foot of the compasses in the centre of Capella, describe an arc towards the north; then with 55 deg. (=90°—35°,) taken in a similar manner, and one foot of the compasses in the centre of Aldebaran, describe another arc, crossing the former; the point of intersection brought to the brass meridian will show the latitude to be 20½ deg. north.

2. The altitude of Markab in Pegasus was 30 deg., and that of Altair in the Eagle, at the same time, was 65 deg.; what was the latitude, supposing it to be north?

3. In north latitude the altitude of Arcturus was observed to be 60 deg., and that of β or Deneb, in the Lion's tail, at the same time, was 70 deg.; what was the latitude?

4. In north latitude, the altitude of Procyon was observed to be 50 deg. and that of Betelgeux in Orion, at the same time, was 58 deg.; required the latitude of the place of observation?

PROBLEM LXXXIX.

The meridian altitude of a known star being given at any place in north latitude, to find the latitude.

RULE. Bring the given star to that part of the brass meridian which is numbered from the equinoctial towards the poles; count the number of degrees in the given altitude on the brass meridian from the star towards the south part of the horizon, and mark where the reckoning ends; elevate or depress the pole till this mark coincides with the south point of the horizon, and the elevation of the north pole above the north point of the horizon will show the latitude.

EXAMPLES. 1. In what degree of north latitude is the meridian altitude of Aldebaran $52\frac{1}{2}$ deg.?

Answer. 53 deg. 36 min. north.

2. In what degree of north latitude is the meridian altitude of β, one of the pointers in Ursa Major, 90 deg.?

3. In what degree of north latitude is γ, in the head of Draco, vertical when it culminates?

4. In what degree of north latitude is the meridian altitude of ϵ or Mirach in Boötes, 68 deg.?

PROBLEM XC.

The latitude of a place, day of the month, and hour of the day, being given, to find the NONAGESIMAL DEGREE* *of the ecliptic, its altitude and azimuth, and the* MEDIUM CŒLI.

RULE. Elevate the north pole to the latitude of the given place, and screw the quadrant of altitude upon the brass meridian over that latitude; find the sun's place in the ecliptic, bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon; but, if the given time be past noon,

* The nonagesimal degree of the ecliptic is that point which is the most elevated above the horizon, and is measured by the angle which the ecliptic makes with the horizon at any elevation of the pole; or, it is the distance beneath the zenith of the place and the pole of the ecliptic. This angle is frequently used in the calculation of solar eclipses. The medium cœli, or mid-heaven, is that point of the ecliptic which is upon the meridian.

turn the globe westward till the index has past over as many hours as the time is past noon, and fix the globe in this position; count 90 deg. upon the ecliptic from the horizon, (either eastward or westward) and mark where the reckoning ends, for that point of the ecliptic will be the nonagesimal degree, and the degree of the ecliptic cut by the brass meridian will be the medium cœli: bring the graduated edge of the quadrant of altitude to coincide with the nonagesimal degree of the ecliptic thus found, and the number of degrees on the quadrant, counted from the horizon, will be the altitude of the nonagesimal degree; the azimuth will be seen on the horizon.

EXAMPLES. 1. On the 21st of June, at forty-five minutes past three o'clock in the afternoon at London, required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the longitude of the medium cœli, and its altitude, &c.

Answer. The nonagesimal degree is 10 deg. in Leo, its altitude is 54 deg., and its azimuth 22 deg. from the south towards the west, or nearly S. S. W. The mid-heaven, or point of the ecliptic under the brass meridian, is 24 deg. in Leo. and its altitude above the horizon, is 52 deg. The degree of the equinoctial cut by the brass meridian reckoning from the point Aries, is the right ascension of the mid-heaven, which in this example is 146 deg. The rising point of the ecliptic will be found to be 10 deg. in Scorpio, and the setting point 10 deg. in Taurus. If the graduated edge of the quadrant be brought to coincide with the sun's place, the sun's altitude will be found to be 39 deg. and his azimuth 78½ deg. from the south towards the west, or nearly W. by S.

2. At London, on the 24th of April, at nine o'clock in the morning; required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the point of the ecliptic which is the mid-heaven, &c. &c.?

3. At Limerick, in 52 deg. 22 min. north latitude, on the 15th of October, at five o'clock in the afternoon, required the point of the ecliptic which is the nonagesimal degree, its altitude and azimuth, the point of the ecliptic which is the mid-heaven, &c. &c.?

4. At Dublin, in latitude 53 deg. 21 min. north, on the 15th of January, at two o'clock in the afternoon; required the longitude, altitude, and azimuth, of the nonagesimal degree; and the longitude and altitude of the mediun cœli, &c. &c.?

Problem XCI

The latitude of a place, day of the month, and the hour, together with the altitude and azimuth of a star, being given, to find the star.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the place, and screw the quadrant of altitude on the brass meridian over that latitude; find the sun's place in the ecliptic bring it to the brass meridian, and set the index of the hour-circle to 12; then, if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the time wants of noon, but, if the time be past noon, turn the globe westward till the index has passed over as many hours as the time is past noon; let the globe rest in this position, and bring the division marked O on the quadrant to the given azimuth on the horizon; then, immediately under the given altitude on the graduated edge of the quadrant you will find the star.

Examples. 1. At London, on the 21st of December, at four o'clock in the morning, the altitude of a star was 50 deg., and its azimuth was 37 deg. from the south towards the east; required the name of the star?

Answer. Deneb, or β in the Lion's tail.

2. The altitude of a star was 27 deg., its azimuth 76½ deg. from the south towards the west, at eleven o'clock in the evening at London, on the 11th of May; what star was it?

3. At London, on the 21st of December, at four o'clock in the morning, the altitude of a star was 8 deg., and its azimuth 51 deg. from the south towards the west; required the name of the star?

4. At London, on the 1st of September, at nine o'clock in the evening, the altitude of a star was 47 deg., and its azimuth 73 deg. from the south towards the east: required the name of the star?

Problem XCII.

To find the time of the moon's southing, or coming to the meridian of any place, on any given day of the month.

Rule. Elevate the pole so many degrees above the horizon as are equal to the latitude of the given place; find the moon's latitude and longitude, or her right ascension and declination, from an ephemeris, and mark her place on the globe; bring the sun's place to the brass meridian, and set the index of the hour-circle to 12; turn the globe westward till the moon's place comes to the meridian, and the hours passed over by the index will show the time from noon when the moon will be upon the meridian.

Or, without the globe.

Find the moon's age, which multiply by 31, and cut off two figures from the right hand of the product, the left hand figures will be the hours; the right hand figures must be multiplied by 60, for minutes.

Or, correctly, thus:

Take the difference between the sun's and moon's right ascension in 24 hours; then, as 24 hours diminished by this difference is to 24 hours, so is the moon's right ascension at noon, diminished by the sun's, to the time of the moon's transit.

Examples. 1. At what hour, on the 10th of April, 1827, will the moon pass over the meridian of Greenwich? The moon's right ascension at midnight being 185 deg. 28 min., and her declination 5 deg. 49 min. south.

Answer. By the Globe.—The moon comes to the meridian about midnight.

By using the Nautical Almanac.

Sun's right ascension at noon 10th April =	1 h.	13′	15″	7
Ditto . . . . . 11th April =	1	16	55	5
Increase of motion in 24 hours .	0	3	39	8

Moon's right ascension at noon 10th April =	178° 47′ 32″
Ditto . , . . 11th April =	192° 16′ 45″
Increase in 24 hours	13° 29′ 13″ equal

to 53′ 56″; hence 59′ 56″ diminished by 3′ 39″, leaves 50′ 17″ the moon motion exceeds the sun's in 24 hours.

Moon's right ascension 178° 47' × 4 =	* 11 h.	55	8"
Sun's right ascension . =	1	13	15.7
	10	41	52.3

24h. --50' 17" : 24h. : : 10° 41' : 11h. 4' the true time of the moon's passage over the meridian in the morning, agreeing within one minute of the Nautical Almanac.

2. At what hour, on the 1st of January, 1827, will the moon pass over the meridian of Greenwich, the moon's right ascension at noon being 328 deg. 43 min., and declination 7 deg. 15 min. south.

3. At what hour, on the 12th of March, 1827, will the moon pass over the meridian at Greenwich, the moon's right ascension at midnight being 164 deg. 41 min., and declination 1 deg. 43 min. north?

4. At what hour, on the 17th of October, 1827, will the moon pass over the meridian of Greenwich, the moon's right ascension at noon being 163 deg. 28 min., and declination 2 deg. 33 min. north?

Problem XCIII.

The day of the month, latitude of the place, and time of high water at the full and change of the moon being given, to find the time of high water on the given day.

Rule. Find the time at which the moon comes to he meridian of the given place by the preceding problem, to which add the time of high water at the given place at the full and change of the moon, and the sum will show the time of high water in the afternoon. If

* When the sun's right ascension is greater than the moon's, 24 hours must be added to the moon's right ascension before you subtract.

the sum exceed 12 hours, subtract 12 hours and 24 minutes from it, and the remainder will show the time of high water in the morning; but if the sum exceed 24 hours, subtract 24 hours and 48 minutes from it, and the remainder will show the time of high water in the afternoon.

Examples. 1. Required the time of high water at London Bridge on the 2d of April, 1827, the moon's right ascension at that time being 78 deg. 23 min, and her declination 20 deg. 4 min. north?

	h	m
Answer, By the Globe.—The moon comes to the meridian at	4h	39′
Time of high water at the full and change at London .	3	0
Time of high water in the morning	7	39

2. Required the time of high water at Hull, on the 25th of May, 1827, the moon's right ascension at noon being 58 deg. 34 min., and her declination 18 deg. 50 min. north?

3. Required the time of high water at Liverpool, on the 22d of June, 1827, the moon's right ascension at noon being 68 deg. 2 min., and her declination 19 deg 39 min. north?

4. Required the time of high water at Limerick, on the 19th of August, 1827, the moon's right ascension at noon being 111 deg. 20 min., and her declination 17 deg. 10 min. north?

5. Required the time of high water at Bristol, on the 9th of September, 1827, the moon's right ascension at noon being 31 deg. 51 min., and her declination 13 deg. 6 min. north?

6. Required the time of high water at Dublin, on

the 12th of October, 1827, the moon's right ascension at noon being 102 degrees 57 min., and her declination 18 deg. 3 min. north?

Problem XCIV.

To describe the apparent path of any planet, or of a comet amongst the fixed stars, &c.

Rule. Draw a straight line o, o, to represent the ecliptic, and divide it into any convenient number of equal parts. Set off eight of those equal parts northward and southward of the ecliptic at each end thereof; and draw lines, as in the figure Plate V.; these will represent the zodiac. Find the planet's geocentric latitude and longitude in an ephemeris, or in the Nautical Almanac, and mark its place for every month, or for several days in each month, beginning at the right hand of the ecliptic line, and proceeding towards the left.*

Find the latitudes and longitudes † of the principal stars in the several constellations near which the planet passes, and set them off in a similar manner from the right hand towards the left; you will thus have a complete picture of any part of the heavens, with the posi-

* The young student will recollect, that the stars appear in a contrary order in the heavens to what they do on the surface of a globe In the heavens we see the concave part, on the globe the convex. This manner of delineating the stars will be found extremely useful, and will enable the student to know their names and places sooner than by the globe.

† The places of the stars may likewise be laid down by their right ascensions and declinations, by drawing a portion of the equinoctial instead of the ecliptic.

tions of the several stars, &c. as they appear to a spectator on the earth.

Example. Delineate the path of the planet Jupiter for the year 1811; the latitudes and longitudes being as follow:*

	Longitudes.	Latitudes.		Longitudes.	Latitudes.
Jan. 1st.	$1^{s}21^{\circ}45'$	$0^{\circ}57'$S.	July 25th	$2^{s}25^{\circ}1'$	$0^{\circ}24'$S.
Feb. 7th	1 22 11	0 47 S.	Aug. 7th	2 27 36	0 23 S.
—— 25th	1 23 58	0 43 S.	—— 19th	2 29 48	0 22 S.
March 1st	1 24 29	0 42 S.	—— 25th	3 0 48	0 22 S.
—— 25th	1 28 16	0 37 S.	Sept. 7th	3 2 45	0 21 S.
April 1st	1 29 35	0 36 S.	—— 25th	3 4 50	0 21 S.
—— 25th	2 4 30	0 32 S.	Oct. 7th	3 5 44	0 20 S.
May 1st	2 5 49	0 31 S.	—— 25th	3 6 15	0 19 S.
—— 13th	2 8 31	0 30 S.	Nov. 1st	3 6 10	0 18 S.
—— 25th	2 11 17	0 29 S.	—— 19th	3 5 12	0 17 S
June 1st	2 12 54	0 28 S.	—— 25th	3 4 40	0 16 S.
—— 25th	2 18 27	0 26 S.	Dec. 13th	3 2 34	0 14 S.
July 7th	2 21 49	0 25 S.	—— 25th	3 0 57	0 12 S.

Jupiter's path, when delineated, will be south of the ecliptic in the order A, B, C, D, E, F, G, H. Thus, he will appear at A on the 1st of January, at B on the 1st of March, at C on the 1st of April, at D on the 1st of May, at E on the 1st of June, at F on the 7th of July, at G on the 25th of August, and at H on the 25th of October. On the 25th of August, when Jupiter appears at G, he will be a little to the right hand of the star marked η in Gemini; when he arrives at H, which will happen on the 25th of October, he will *apparently* return again to G, a small matter above his former path,

* As Jupiter performs his revolution round the sun in 11 years 315 days, he will have nearly the same longitude in the years 1823 and 1835, consequently he will pass through the same constellations as are delineated in Plate V.

where he will be situated on the 25th of December. Jupiter will not be visible during the *whole* of his apparent progress from A to H, being too near to the sun during the months of *May* and *June.*

In the same manner the places and situations of the stars may be delineated; thus, Aldebaran, the principal star in the Hyades, will be found by the globe, (or a proper table) to be situated in 7° of ♊ and in 5¾° of south latitude; Betelgeux in Orion's right shoulder in about 26° of ♊ and 16° of south latitude, and its place may be laid down on a map by extending the line of its longitude, as from L, till it meets a straight line passing through 16, 16, on the sides of the map. In the same manner any other star's situation may be described; thus the Hyades will appear at Q, the Pleiades at P, &c. and Bellatrix, &c. as in the figure.

The constellation Orion, here described, is a very conspicuous object in the heavens in the months of January and February, about 9 or 10 o'clock in the evening, and will be an excellent guide for determining the positions of several other constellations, particularly Canis Major, Canis Minor, Auriga, &c.

QUESTIONS

FOR EXAMINATION OF PUPILS.

CHAPTER I.

What is the terrestrial globe?—the celestial?

What is the axis of the earth?

How is it represented?

What are the poles of the earth?—the celestial poles?

What is the brazen meridian?

How is it divided?—marked?

What are great circles?—small circles?—meridians? When is it noon? What is the first meridian?—the equator?

How are the latitudes of places reckoned?—the longitudes?

What is the equinoctial?

How are declinations and right ascensions reckoned?

What is the ecliptic?—the zodiac? How are the ecliptic and zodiac divided? Name the spring signs—summer—autumnal—winter.

Which are the ascending signs?—the descending signs?

What are the colures?

How do they divide the ecliptic?

What is meant by *declination?*

When has the sun no declination?

When is his declination north?—when south?—when greatest?

What is the greatest declination of a star?—a planet?

What are the tropics? Of what are they the limits?

What are the polar circles?

What are parallels of latitude?

Is their number limited?

What is the hour-circle on the artificial globe? How is it divided? What is its use?

What is the horizon?—the sensible horizon?—the rational horizon?—the wooden horizon of the artificial globe?

What is marked on its first circle?—the second—third—fourth—fifth sixth—seventh—eighth?

What are the cardinal points of the horizon?—of the heavens?—of the ecliptic?

What is the zenith?—the nadir?

What is the pole of any circle? Give examples.

What are the equinoctial points?—the solstitial?

What happens when the sun is one of the equinoctial points?—the solstitial?

What is an hemisphere?

What hemisphere does the horizon divide?—the equator?—the brass meridian?

What is the Mariner's compass?

Describe it.

What is the variation of the compass?

When is the variation east?—when west?

What is the variation in England?

What is the latitude of a place?—how reckoned?—The latitude of a star or planet?—how reckoned? What is the greatest possible latitude of a star?—a planet?—of the sun?

What is the quadrant of altitude?

What is the use of the upper division?—the lower?

What is the longitude of a place?—how reckoned? What is the greatest possible longitude of a place?

What is the longitude of a star or planet?—of the sun?

What are almacanters?

Are they drawn on the globe? How are they described?

What are parallels of celestial latitude?—parallels of declination?—Azimuth or vertical circles?

What are measured on them

How are they represented?

What is the prime vertical?

What is the altitude of any object in the heavens?

When is it called meridian altitude?

What is the zenith distance of a celestial object?—when is it called meridian zenith distance?

What is the polar distance of any celestial object?

What is the amplitude of an object in the heavens? For what is it used? When has the sun north amplitude?—when south? When has it none?

What is the azimuth of a celestial object?

What are hour-circles?

What is meant by a right sphere?—a parallel sphere?—an oblique sphere?

What is meant by climate?

What is a zone? How many are there? How many climates are there? What is the torrid zone? What opinion was entertained by the ancients? What are the temperate zones—the frigid zones? What is meant by amphiscii?—ascii?—heteroscii?—periscii?—antœci?—periœci?—antipodes?—right ascension?—oblique ascension?—oblique descension?—ascensional or descensional difference?—crepusculum?—the angle of position?

What method of describing the stars is now used? Who invented it? How has it been further enlarged? How are double stars designated?—how discovered?

Repeat the Greek alphabet?

What is meant by the diurnal arc?—the noctural arc?—aberration?

THE END.

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