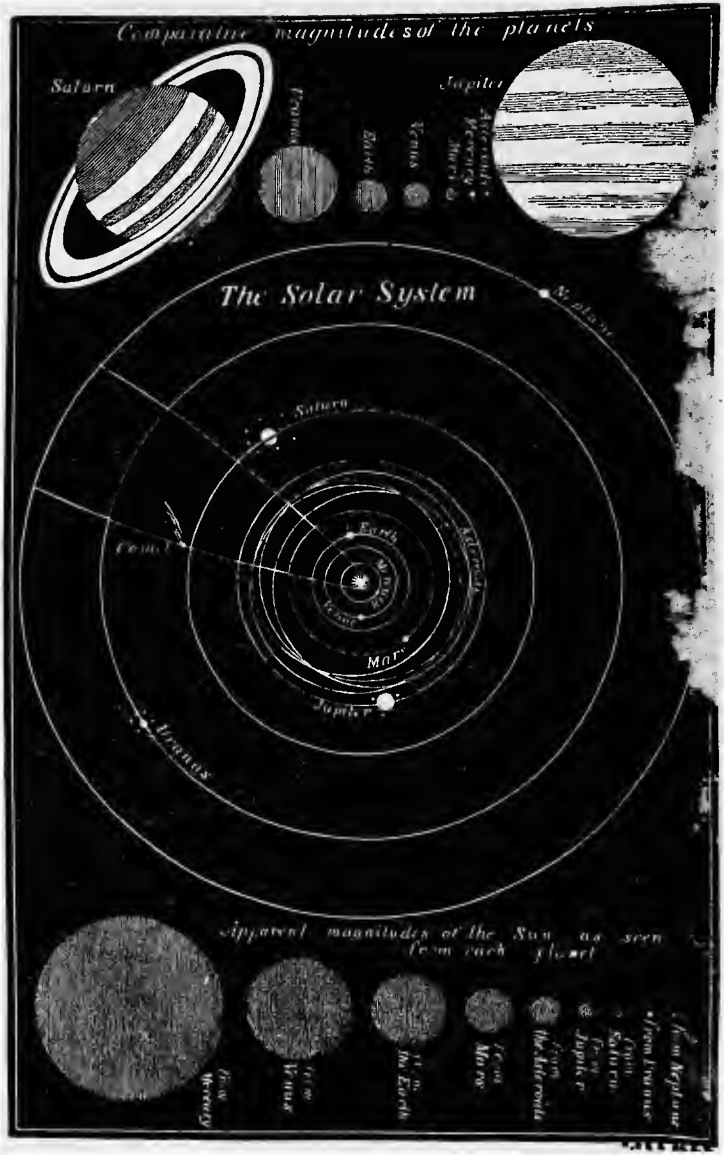
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A NEW TREATISE ON ASTRONOMY, AND THE USE OF THE GLOBES,

IN TWO PARTS.

CONTAINING ASTRONOMICAL AND OTHER DEFINITIONS; MOTIONS AND POSITIONS OF THE SUN, MOON, AND PLANETS; KEPLER'S LAWS AND THE THEORY OF GRAVITATION; REFRACTION, TWILIGHT AND PARALLAX; CONNECTIONS, PERIODS, DISTANCES, PHENOMENA, AND MAGNITUDES OF THE HEAVENLY BODIES, COMPOSING THE SOLAR SYSTEM, &C. ALSO, AN EXTENSIVE COLLECTION OF THE MOST USEFUL PROBLEMS ON THE GLOBES, ILLUSTRATED BY A SUITABLE VARIETY OF EXAMPLES, &C.

DESIGNED FOR THE

USE OF HIGH SCHOOLS AND ACADEMIES.

BY JAMES M'INTIRE, M. D.,

PROFESSOR OF MATHEMATICS AND ASTRONOMY IN THE CENTRAL HIGH SCHOOL OF BALTIMORE.

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PREFACE.

The general extension of navigation and commerce over our globe, the numerous inventions and discoveries which have characterized the last and the present century, the number of travellers who have traversed the earth in all directions in pursuit of philosophical knowledge, the restlessness of inflamed curiosity, and even the wars, invasions and revolutions of our eventful age, have all co-operated to enlarge the sphere of human knowledge, and consequently our acquaintance with the phenomena of the earth, and with the evolutions of those heavenly orbs which decorate that immense vault surrounding our destined habitation. The learned men of the present age are better acquainted with the figure of the earth, and the planetary magnitudes and distances than their predecessors a few centuries back, were with the magnitude and position of their respective native countries.

Hence, it has been found necessary to enlarge the system of school education, and to allow a liberal space to the sublime, interesting and useful science of Astronomy. We have been led into this course, not merely by the desire of gratifying a liberal curiosity, but by the necessity of qualifying men, holding a respectable rank in society, for the discharge of the various duties of life. The philosopher, the theologian, the physician, the statesman, the merchant, and above all, the navigator, are at present supposed, to have at least, a general acquaintance with the heavenly bodies, and the unerring laws by which they are regulated and governed. Even well-educated females are expected to have added a competent share of astronomical knowledge to the other accomplishments of their sex.

Therefore, in all our schools and institutes of education, male and female, Astronomy is justly becoming a favorite study, having all the advantages, we may be allowed to say, of opening to the youthful mind a view of the beautiful visions of planetary motions, and of the other charms of the science, which never fail to inspire rapturous feelings of delight, and to create a genuine taste for the beauties and sublimities of nature. Intimately connected with Astronomy is the Use of the Globes, the study of which is recommended by nearly all the writers on the different branches of education.

A treatise on Astronomy and the Use of Globes, calculated for the use of High Schools and Academies seems to be wanted. The small compends, which are commonly met with, are too puerile and trifling, and in every view incompetent to the attainment of their object. With these impressions, and from long experience in the education of youth, the ensuing treatise has been undertaken and prepared.

Part First of the present volume, it is believed, contains everything of importance, relating to the elements of astronomical science, and is divided into articles, each of which, for convenience in reference, is numbered, and exhibits the subject under discussion in that article. Students of ordinary attainments, can, with proper application, understand and answer nearly all the questions on the different articles, and corresponding in number, found at the foot of each page. Some knowledge of Geometry, Trigonometry, and Algebra, is requisite fully to comprehend a few of the more difficult demonstrations and abstruse calculations.

Part Second, contains an extensive collection of the most useful Problems on the Globes, illustrated by a suitable variety of examples, with notes and observations. These problems will be found very entertaining and instructive to the young student. They explain some of the most important branches of Geography and Astronomy. A few of the most useful tables are given in this part, and the method of their calculation fully explained.

The design of the author in the present treatise, is to produce a work on Astronomy and the Use of the Globes, suited to the exigencies of school instruction; to supply on the one hand the defects of the smaller compends, and on the other to convey to the pupil a comprehensive knowledge of these subjects in one volume of but moderate size. With what degree of judgment this attempt has been made, the public will determine, against whose decision there is no appeal; but it is hoped that they will receive with indulgence a well meant effort to simplify the system of education, and thus promote the diffusion of useful knowledge.

CENTRAL HIGH SCHOOL,
BALTIMORE, Dec. 1849.

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CHAPTER I.

PHENOMENA OF THE HEAVENS.—TERRESTRIAL AND CELESTIAL GLOBES OR SPHERES—DEFINITIONS OF POINTS, LINES, CIRCLES, AND TERMS, USED IN OBSERVATIONS, COMPUTATIONS, AND IN THE SOLUTION OF PROBLEMS PERTAINING TO GEOGRAPHY AND ASTRONOMY.

1. Heavenly Bodies. The Sun, Moon, and Stars, and all luminous bodies situated in the regions of space surrounding the earth, are called the Heavenly Bodies.

2. Phenomena of the Heavenly Bodies. When we view attentively, in our latitude, the nocturnal heavens at successive intervals, we shall find that the stars appear to move from that part of the heavens called the East, to that part called the West. With our left to the east. we observe some stars to come into view, or rise, gradually ascend during one-half of their course, then gradually descend, and disappear, or set. The arcs described by these stars, from their rising to their setting, are parallel, and gradually decrease in length and height, towards the front, from the one passing over our heads, which is the most elevated. A line which joins the most elevated points of these arcs, lies in the direction of that part of the heavens called the South.

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1. Name the heavenly bodies.
2. Give a description of the phenomena of these bodies.

If we now turn our right to the east, and carefully observe the motions of the stars in our front, we shall find that some, from their rising to their setting, will describe arcs which increase from the one passing over our heads, to a complete circle; and that others will revolve, in circles of different dimensions, round a certain star which appears to remain stationary. This star is called the Pole Star; and those that revolve round it, and never set, are called Circumpolar Stars. The pole star is not in reality stationary, but revolves, itself, and the other stars near it, round a certain and fixed point. This point, which is about 1½° from the pole star, is called the North Pole of the Heavens. It will thus be found, that the sun, moon, and all the heavenly bodies, appear to make one complete revolution in the course of nearly twenty-four hours, called their Diurnal Motion.

3. Fixed Stars and Planets. Of these stars, by far the greatest number maintain always the same relative positions with respect to each other, and are therefore called Fixed Stars. But, by carefully inspecting the heavens, a few others will be found to change their position among the fixed stars—sometimes moving to the east of them, at other times to the west, and at certain times remaining stationary. These bodies are called Planets.* If the situation of the sun and moon be observed at successive intervals, we shall find that they have a motion from west to east among the fixed stars, and that each will perform a revolution in the heavens, in different periods of time.

4. Artificial Globes. The Terrestrial Globe is an artificial representation of the earth; having truly delineated on its surface, according to their relative situation on the earth, the four quarters of the world, the differ-

* From πλανητης a wanderer.

What are circumpolar stars? How is the north pole of the heavens found? What is meant by the diurnal motion of the heavenly bodies?

3. How would you distinguish between the fixed stars and planets? Besides the diurnal motion, what other motion have the sun and moon?

4. What is the terrestrial globe?

ent empires, kingdoms, countries, and states; the several oceans, seas, largest lakes, and principal rivers; the chief cities, towns, &c.

The Celestial Globe is an artificial representation of the heavens; having the fixed stars laid down on its surface, according to their natural order and position in the heavens. The student must suppose himself placed in the centre of this globe, and viewing the stars in the concave surface.

The distance of the fixed stars is so immensely great, that from opposite positions of the earth's surface, or even orbit, they sensibly appear to occupy the same point in the heavens; and hence, from all places of the earth, and at all seasons of the year, the stars maintain the same apparent position. As the other heavenly bodies, namely, the planets, &c., are subject to relative and actual change of place, they are not delineated on this globe, but when their places are found for any particular time they are referred to these points in the same spherical concave surface, whatever may be their actual distance from the earth.

5. Axes and Poles of the Heavens and Earth. If we imagine a straight line to be drawn from the north pole of the heavens, already determined, (2,*) to the centre of the earth, and extended, it will be the Axis of the Heavens, or the line on which they appear to revolve from east to west. The opposite extremity of this line will determine the south pole of the Heavens.

That part of the axis of the heavens which is supposed to pierce the earth and pass through its centre, is that imaginary line on which it revolves from west to east,

* Numbers thus enclosed in a parenthesis, refer to previous articles.

What is the celestial globe? In using this globe, where must the student suppose himself situated? Why are the fixed stars only laid down on this globe? What heavenly bodies are not delineated on this globe, and why? When the place of any of these heavenly bodies is found for any time, to what point must it be referred, and without regard to what?

5. What is the axis of the heavens? What is the axis of the earth? What are the terrestrial and celestial poles?

and is called the Axis of the Earth. The extremities of this axis are the Poles of the Earth. The one is called the north or Arctic Pole; and the other, the south or Antarctic Pole.

The wires on which the artificial globes revolve, represent respectively the axis of the heavens and the earth; and the extremities of these wires represent the celestial and terrestrial poles.

6. Great and Small Circles. The circles of the terrestrial and celestial spheres are either great or small. A great circle is a section made by a plane, which passes through the centre of the sphere, and divides it into two equal parts. A small circle is a section made by a plane, which does not pass through the centre of the sphere, and consequently divides it into two unequal parts.

Two great circles bisect each other, because their common intersection, being a straight line, and passing through the centre, is a diameter.

7. Terrestrial and Celestial Equator. The terrestrial equator, simply called the Equator, is a great circle* of the earth, the plane of which is perpendicular to the axis, and at an equal distance from the poles. It divides the earth into two hemispheres, the northern and southern. When the plane of the terrestrial equator is referred to the heavens, it coincides with the celestial equator, generally called the Equinoctial, because when the sun comes to it, the days and nights are equal all over the world. The celestial poles are evidently the geometrical poles of the celestial equator.

8. The Horizon. The horizon is a great circle sepa-

* The term circle is frequently used for its circumference.

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6. Define a great and small circle of the sphere. Why do two great circles bisect each other?

7. What is the terrestrial equator, and how does it divide the earth? What is the celestial equator, and what generally called? Why is the celestial equator called the equinoctial?

8. What is the horizon, and how distinguished?

rating the visible half of the heavens from the invisible, and is either Sensible or Rational. The sensible horizon of any place on the earth's surface, is a circle, the plane of which is tangent to the earth at that place, and cuts the celestial sphere. The rational, or true horizon, is a plane supposed to pass through the centre of the earth parallel to the visible or sensible horizon. The upper pole of this circle is called the zenith, and the lower pole is called the nadir.

The Wooden Horizon which circumscribes the artificial globe, is a representation of the rational horizon. It is divided into several concentric circles. On the globes generally in use, these circles are arranged as follows:

The first circle is divided into degrees, which are numbered from 0° to 90°, from the east towards the north and south, and and in like manner from the west towards the north and south.

The second circle contains the 32 points of the compass. The north and south points are exactly in the direction of the poles of the globe.

The third circle contains the 12 signs of the zodiac, with the figure and character of each sign.

The fourth circle contains the degrees of the signs, each sign comprehending 30°.

The fifth circle contains the days of the month, answering to each degree of the sun's place in the ecliptic.

The sixth circle contains the 12 calendar months of the year.

The seventh circle shows the equation of time. When the clock ought to be faster than apparent time, the number of minutes showing the difference is marked by the sign +; and when the clock ought to be slower, the number of minutes expressing the difference, is marked by the sign —.

The Compass attached to the frames of some artificial globes, is a circle divided into 32 equal parts, called Points, each containing 11° 15′, conformable to the same number

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What is the sensible horizon? What is the rational horizon? What is the zenith? What the nadir? What does the wooden horizon represent? How is the wooden horizon divided? Describe the several circles of the wooden horizon. Describe the compass.

of points on the wooden horizon. In the centre there is a finely-pointed pin, on which is placed a Magnetic Needle moving freely, and protected by a glass cover.

The compass serves to set the globe due north and south, in order that its circles, lines, &c., may correspond to those which they represent.

The Variation of the Compass is the deviation of the north end of the needle from the true north point of the horizon, and is either east or west. Proper allowance should be made for the variation.

Rhumb Lines are lines drawn from the centre of the compass to the 32 points of the horizon.

In navigation, a rhumb line is a loxodromic curve, cutting each meridian at the same angle, and is traced by a ship sailing on a given course by the compass; hence, it is a *spiral*, and it will never return into itself except it be due east and west, or due north and south.

9. Meridians. Meridians are great circles cutting the equinoctial at right angles, and consequently bisecting each other in the celestial poles. These great circles receive different names, such as Celestial Meridians, Hour Circles, and Declination Circles. Horary Angles are the angles formed by these circles.

The Colures are those two meridians which pass through the equinoctial and solstitial points; hence they are called the equinoctial and solstitial colures.

The half of the meridian above the horizon is called the Superior Meridian, and the other half below, the Inferior Meridian. These Circles, when referred to the earth, are called Terrestrial Meridians; but often indiscriminately they are simply called Meridians. Every place on the earth is supposed to have a meridian passing

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Of what use is the compass? What is the variation of the compass, and what is observed respecting it? Describe the rhumb lines, and particularly as understood in navigation.

9. What are meridians, and where do they bisect each other? What are the different appellations given to these great circles? What are the colures, and how distinguished? What is the superior, and also inferior meridian? What are terrestrial meridians?

through it. When the sun comes to the meridian of any place (not within the polar circles,) it is apparent noon at that place.

The First or Prime Meridian is that from which the longitudes of places begin to be reckoned, and passes through some noted place. All nations have not fixed on the same first meridian. In English globes, the first meridian is supposed to pass through London or the Royal Observatory at Greenwich. The Americans generally reckon longitude from the meridian of Washington City.

The Brass Meridian is a great circle, which divides the globe into the eastern and western hemispheres, and within which it revolves. When any place is brought to the brass meridian, it becomes the meridian of that place. The brass meridian is divided into 360°, which are again sub-divided into halves and quarters. The degrees of one semi-circle of the brass meridian are numbered from the equator towards the poles, and those of the other, from the poles towards the equator.

The Hour Circle is a small circle of brass fixed to the north pole of the artificial globes, and divided into 24 equal parts, corresponding to the hours of the day, and also to the meridians or hour circles passing through every 15° of the equator or equinoctial. The hours on the hour circle are sub-divided into halves and quarters. On some globes, the hour circle is drawn surrounding the north pole, and furnished with an Index, or pointer.

10. THE ECLIPTIC AND ZODIAC WITH THEIR SIGNS. That great circle, which the sun appears to describe by his annual progress in the heavens, is called the Ecliptic. The plane of this circle, which necessarily contains the

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When the sun comes to the meridian of any place, what hour is it at that place? What is the first meridian, and through what place is it supposed to pass respectively by the English and Americans? What is the brass meridian, and how divided? How are the degrees in each semi-circle of the brass meridian numbered? What is the hour circle, and to what do its divisions correspond?

10. What is the ecliptic, and through what does it pass?

earth's orbit, passes through the centres of the sun and earth, and cuts the plane of the equinoctial in an angle of 23° 28′, called the Obliquity of the Ecliptic; the points of intersection are called the Equinoctial Points. The intersection of the plane of the ecliptic with the earth's surface is drawn on the terrestrial globe, and is also called the ecliptic; so also the points of intersection with the equator, are called the equinoctial points.

The Zodiac is a zone or belt, which extends about 8° on each side of the ecliptic, and contains the orbits of the moon and principal planets. This zone or belt is drawn on the celestial globe.

The ecliptic and zodiac are divided into twelve equal parts, called Signs, each containing 30°. The first six, commencing at the point where the sun passes from the south to the north of the equinoctial, are called Northern Signs, the other six, Southern Signs. The names and characters of the signs, with the days, or thereabouts, on which the sun enters them, are as follows:

NORTHERN SIGNS.

SPRING.	♈	Aries, the Ram, 20th of March.
	♉	Taurus, the Bull, 19th of April.
	♊	Gemini, the Twins, 20th of May.
SUMMER.	♋	Cancer, the Crab, 21st of June.
	♌	Leo, the Lion, 22d of July.
	♍	Virgo, the Virgin, 22d of August.

SOUTHERN SIGNS.

AUTUMN.	♎	Libra, the Balance, 23d of September.
	♏	Scorpio, the Scorpion, 23d of October.
	♐	Sagittarius, the Archer, 22d of November.
WINTER.	♑	Capricornus, the Goat, 21st of December.
	♒	Aquarius, the Water-bearer, 20th of January.
	♓	Pisces, the Fishes, 19th of February.

What is the obliquity of the ecliptic? What are the equinoctial points? Point out the ecliptic and equinoctial points on the globe. Describe the zodiac, and on what globe is it drawn? Into how many signs are the ecliptic and zodiac divided? At what point does the division of the signs begin? Name the northern signs, and the days on which the sun enters them. Name the southern signs and the days on which the sun enters them.

11. VERTICAL, OR AZIMUTH CIRCLES. Vertical Circles are imaginary great circles cutting the horizon at right angles, and consequently passing through the zenith and the nadir.

The Prime Vertical cuts the meridian at right angles. Its intersections with the horizon are the east and west points.

The Quadrant of Altitude, used in solving problems by the globes, is a thin slip of brass, divided on one edge from 0° upwards to 90°, and from 0° downwards to 18°, corresponding to as many degrees of any great circle of the globe.

When the quadrant of altitude is screwed on the brass meridian over the zenith of the place, and the lower end passed between the globe and wooden horizon, it will represent a part of a vertical great circle.

12. CIRCLES OF CELESTIAL LATITUDE. Great circles of the celestial sphere drawn at right angles to the ecliptic, and consequently passing through its poles, are called Circles of Celestial Latitude.

The quadrant of altitude, when screwed on the brass meridian over the pole of the ecliptic, and its lower end moved along this circle, will represent parts of these circles of celestial latitude.

13. CARDINAL POINTS. The cardinal points of the heavens are the Zenith and the Nadir. The zenith is the point in which a vertical line at any place meets the heavens above; and the nadir is the point in which this line meets the heavens below. The zenith and nadir as before observed, are the geometrical poles of the horizon.

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11. What are vertical circles, and through what do they pass? What is the prime vertical, and its intersections with the horizon, called? What is the quadrant of altitude? When screwed on the zenith of the place, what does it represent?

12. What are circles of celestial latitude, and how can the quadrant of altitude be made to represent them?

13. What are the cardinal points of the heavens? Describe the zenith. Describe the nadir.

The cardinal points of the horizon are the East, West, North, and South Points. The north and south points are those points in which the meridian of the place cuts the horizon; and the east and west points are those in which the prime vertical circle also cuts the horizon.

The cardinal points of the ecliptic are the Equinoctial and Solstitial Points. The equinoctial points, or Equinoxes, are the intersections of the ecliptic and equinoctial, and are the first points of the signs Aries and Libra. The first point of Aries, or that which the sun passes on the 20th of March, is called the Vernal Equinox; and the first point of Libra, or that which he passes on the 23d of September, is called the Autumnal Equinox. These times or epochs are also termed equinoxes. The solstitial points, or Solstices, are those two opposite points of the ecliptic, 90° distant from the equinoctial points, and are therefore the first points of the signs Cancer and Capricornus. The first point of the sign Cancer, or that which the sun enters on the 21st of June, is called the Summer Solstice; and the first point of the sign Capricornus, or that which he enters on the 21st of December, is called the Winter Solstice. These dates are also called solstices.

14. Small Circles of the Spheres. Parallels of Declination are small circles parallel to the equinoctial. Parallels of Latitude are small circles parallel to the Equator.

Every place on the globe is supposed to have a parallel of latitute drawn through it, though they are only drawn through every 10° of latitude on the terrestrial globe.

Of what are the zenith and nadir the poles? What are the cardinal points of the horizon? Describe the north and south points, and also the east and west points. What are the cardinal points of the ecliptic? What are the equinoctial points, and on what days does the sun enter them? When do the vernal and autumnal equinoxes happen? What are the solstitial points, and on what days does the sun enter them? When do the summer and winter solstices happen?

14. What are parallels of declination?

Parallels of Celestial Latitude are small circles drawn on the celestial globe, parallel to the ecliptic.

The Tropics are those two parallels of declination, each at a distance of 23° 28′ from the equinoctial, equal the obliquity of the ecliptic, (10). Hence the tropics touch the solstitial points. The northern is called the Tropic of Cancer, and the southern, the Tropic of Capricorn.

The Polar Circles are those two parallels of declination at a distance of 23° 28′ from the celestial poles, equal the obliquity of the ecliptic. The northern is called the Arctic Circle, and the southern, the Antarctic Circle.

The tropics and polar circles are also drawn parallel to the equator on the terrestrial globe, or sphere.

15. Positions of the Sphere. The positions of the sphere are three: right, parallel, and oblique.

A Right Sphere is that position in which the horizon cuts the equator and parallels of latitude, and also their corresponding circles in the heavens, at right angles, dividing them into two equal parts, and thereby making equal day and night. The inhabitants of the equator, because the equinoctial passes through their zenith and nadir, have this position of the sphere.

A Parallel Sphere is that position in which the equator coincides with the rational horizon, and all the parallels of latitude parallel thereto. In this position the zenith and nadir will agree with the celestial poles; hence the inhabitants of the north and south poles (if there be any,) have a parallel sphere.

An Oblique Sphere is that position in which the rational horizon cuts the equator and parallels of latitude obliquely.

In what do parallels of latitude and parallels of celestial latitude differ? What are the tropics, and how distinguished? What are the polar circles, and how distinguished? Point out these small circles on the globes.

15. How many positions of the sphere are there, and what are they? What is a right sphere, and what inhabitants have this position? What is a parallel sphere? What places have a parallel sphere? What is an oblique sphere?

All inhabitants of the earth have an oblique sphere, except those who live at the equator and at the poles.

16. Right Ascension and Declination. The Right Ascension of a heavenly body is an arc of the equinoctial, reckoning from the vernal equinox eastward, to the declination circle passing through the centre of the body. It is also that degree of the equinoctial which rises with the body in a right sphere; because, in this position of the sphere, any meridian or declination circle, and the horizon which regulates the rising of the body, will coincide. The right ascension varies from 0° to 360°, or from 0h. to 24h.

The Declination of a heavenly body is its distançe from the equinoctial, and is either north or south: or, it is an arc of a declination circle intercepted between the centre of the body and the equinoctial. Hence, when the sun enters Aries and Libra, he has no declination; and when he enters Cancer and Capricorn, he has the greatest declination, which is 23° 28′.

The declination of the planets will depend on the inclinations of their orbits and the longitudes of the nodes. As the fixed stars occupy all points of the heavens, their declinations will vary from 0° to 90° north or south. The declination of any particular star is always the same.

The Polar Distance of a heavenly body is its distance from the nearest celestial pole; or, it is the complement of the declination.

When the right ascention and declination of a heavenly body are determinated, its position in the sphere of the heavens is also determined.

What inhabitants have this position?

16. What is the right ascension of a heavenly body? From what is it reckoned, and which way? What is declination, and when has the sun no declination and the greatest declination? On what will the declination of the planets depend? Why does the declination of any particular star not vary? How is the polar distance of any heavenly body found? When is the position of any body in the sphere of the heavens determined?

17. Oblique Ascension and Descension. Ascensional, or Descensional Difference. The oblique Ascension of a heavenly body is that degree of the equinoctial which rises with the body in an oblique sphere, and is reckoned from the first point of Aries eastward round the globe.

The Oblique Descension of a heavenly body is that degree of the equinoctial which sets with the body in an oblique sphere, and is also reckoned from the first point of Aries eastward round the globe.

The Ascensional, or Descensional Difference is the difference between the right and oblique ascension; or, it is the difference between the right and oblique descension; the one difference from the property of the sphere and its circles being always equal to the other.

This difference with respect to the sun, is the time he rises before, and sets after, six o'clock in the summer; or, it is the time he rises after, and sets before, six o'clock in the winter.

18. Latitude and Longitude. The Latitude of a place is an arc of the terrestrial meridian intercepted between the place and the equator, and is either north or south, according as the place is north or south of the equator. Or, the latitude of a place is its distance in degrees from the equator, measured on the arc of a great circle.

The brass meridian of the terrestrial globe measures the latitude of any place. An arc of the celestial meridian, intercepted between the zenith of any place and the equinoctial, is equal to the latitude of that place, and is called the Astronomical Latitude.* The greatest latitude a place can have, is 90°.

* There is a small difference between the astronomical latitude of a place, and its distance in degrees from the equator, on account of the ob-

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17. What is the oblique ascension of a body, and from what point reckoned? What is the oblique descension of a body, and from what point reckoned? What is the ascensional or descensional difference? What does this difference determine with respect to the sun?

18. What is the latitude of a place, and how measured on the terrestrial globe?

The Difference of Latitude between two places is an arc of a meridian, contained between the parallels of latitude of the two places, and cannot exceed 180°.

The Longitude of a place is an arc of the equator intercepted between an assumed meridian and the meridian of the place, and is either east or west, according as the latter meridian is to the east or west of the former meridian. The greatest longitude a place can have, is 180°, or half way round the globe from the first, or assumed meridian.

The Difference of Longitude between two places is an arc of the equator, intercepted between the meridians of the two places, and cannot exceed 180°.

The latitude and longitude of a place, being analogous to the right ascension and declination of a heavenly body, designate its situation on the surface of the earth.

The Latitude of a heavenly body is an arc of the circle of latitude, intercepted between the body and the ecliptic, and is either north or south, according as the body is north or south of the ecliptic. Or, it is the distance of the body in degrees from the ecliptic.

The quadrant of altitude is used in measuring the latitude of the stars on the celestial globe. The sun being always in the ecliptic, has no latitude.

The Longitude of a heavenly body is an arc of the ecliptic, intercepted between the first point of Aries or the vernal equinox, reckoning eastward, and the circle of latitude passing through the centre of the body. The longitude of the sun is his place in the ecliptic.

lateness of the earth. This difference is called the Reduction of Latitude; and when applied to the astronomical latitude, the result is called the Reduced Latitude.

What is the difference of latitude between two places? What is the longitude of a place, and the difference of longitude between two places? What do the latitude and longitude of a place designate with regard to it? What is the latitude of a heavenly body, and why has the sun no latitude? What is the longitude of a heavenly body, and particularly with regard to the sun?

The latitude and longitude of a heavenly body being deduced from the observed right ascension and declination, also determine its place in the sphere of the heavens.

The Geocentric latitudes and longitudes of the planets, are their latitudes and longitudes as seen from the centre of the earth.

The Heliocentric latitudes and longitudes of the planets, are their latitudes and longitudes as seen from the centre of the sun.

19. Altitude and Azimuth. The Altitude of any heavenly body, is an arc of the vertical circle, contained between the centre of the body and the horizon. When the body is on the meridian, its altitude is called the Meridian Altitude.

The Zenith Distance of any heavenly body, is the complement of the altitude, or the distance of the body from the zenith.

When a star or planet comes to the meridian of any place, it is said to Culminate; its altitude at that place being then the greatest. The time at which the moon comes to the meridian of any place, is called the Moon's Southing.

The Azimuth of any heavenly body, is an arc of the horizon, intercepted between the vertical circle passing through the centre of the body, and the north or south point of the horizon.

The altitude and azimuth of a heavenly body determine its position in the *visible hemisphere* of the heavens.

Almacanters, or Parallels of Altitude, are imaginary small circles parallel to the horizon.

What do latitude and longitude determine with regard to a heavenly body? What are the geocentric and heliocentric latitudes and longitudes of the planets?

19. What is the altitude of a heavenly body? What its zenith distance? When is a star or planet said to culminate? What is azimuth? What do altitude and azimuth determine? What are almacanters, and how described?

If the upper end of the quadrant of altitude be screwed over the zenith of the place, and its lower end moved round the horizon, it will describe these circles.

The Angle of Position between two places on the earth, is an angle formed at one of the places by the terrestrial meridian of that place and a great circle passing through the other, and is therefore measured by an arc of the horizon of the first place.

The angle of position is similar to azimuth, which may be considered the angle of position between the zenith of the place of observation and the heavenly body.

20. Amplitude. The Amplitude of any heavenly body is an arc of the horizon intercepted between the centre of the body when rising or setting, and the east or west point of the horizon.

At the time of the equinoxes, namely, on the 20th of March and the 23d of September, the sun rises in the east point and sets in the west point. During our summer, the sun rises and sets north of these points; and during our winter, he rises and sets south of the same points. At the time of the solstices, namely, on the 21st of June and 21st of December, the rising and setting amplitude will be the greatest possible. The amplitude of the sun at any place on the equator will always be equal to his declination, because in this position of the sphere, the arc of the horizon, which measures the amplitude, will coincide with the arc of the meridian, which measures the declination.

21. Planets and their Satellites. The Planets are opaque bodies like our earth, moving round the sun, and shining by the reflection of his light. They are distinguished into primary and secondary.

Describe these circles? What is the angle of position between two places on the earth, and to what is it similar?

20. What is the amplitude of any heavenly body? When has the sun no amplitude, and when the greatest? Where is the sun's amplitude always equal to his declination?

21. What are the planets, and how distinguished?

The Primary Planets move round the sun as their centre of motion. There are seventeen primary planets known, namely, eight large planets, and nine small ones, called asteroids. The large planets are, Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune; and the asteroids are, Vesta, Juno, Ceres, Pallas, Astræa, Hebe, Flora, Iris, and Metis.

The Secondary Planets, Satellites, or Moons, move round the primary planets as their centre of motion. There are eighteen secondary planets or satellites known. The Earth has one, Jupiter four, Saturn seven, and Uranus six.

The Discs of the sun, moon, and planets, are their apparently flat and circular phases. The twelfth part of the sun or moon's apparent diameter or disc, is called a Digit.

22. Orbits and Nodes. The Orbit of a primary planet, is that imaginary path, which it describes round the sun; and the orbit of a secondary planet is the path, which it describes round its primary.

The Nodes are the two opposite points in the ecliptic, where the orbit of a planet appears to intersect it. That node from which the planet ascends northward from the ecliptic, is called the ascending node; and the other from which the planet descends southward, is called the descending node.

23. Aspect of the Sun, Stars, and Planets. The Aspect of the sun, stars and planets, is their situation with respect to each other. There are three principal aspects, namely, conjunction, opposition, and quadrature.

Describe the primary planets, and give their names. How many satellites are known, and to what primary planets do they belong? What are the discs of the sun, moon, and planets? What is the twelfth part of the sun or moon's apparent diameter called?

22. Describe the orbits both of the primary and secondary planets. What are nodes: also the ascending and descending nodes?

23. What is the aspect of the sun, stars, and planets? What are the three principal aspects?

A celestial body is in Conjunction with another when it is in the same point of the heavens with that body, or when its longitude is the same. When the heavenly body is between the earth and the sun, it is in inferior conjunction; and when the sun is between the earth and the body, in superior conjunction.

Two celestial bodies are in Opposition when they are in opposite points of the heavens, or when their longitudes differ 180°.

When the longitudes of two heavenly bodies differ 90° or 270°, that is, when they are three signs, or the fourth part of a circle from each other, they are said to be in Quadrature.

The Elongation of a planet is the Angle formed at the earth by two imaginary lines; the one supposed to be drawn to the sun, and the other to the planet.

24. Poetical Rising and Setting of the Stars. The ancient poets took notice of the rising and setting of the stars in reference to the rising and setting of the sun.

When a star rose at sun-setting, or set with the sun, it was said to rise and set Achronically.

When a star rose with the sun, or set when the sun rose, it was said to rise and set Cosmically.

When a star first became visible in the morning, after having been so near the sun as to be hid by the splendor of his rays, or when it first became invisible in the evening, on account of its nearness to the sun, it was said to rise and set Heliacally.

25. Diurnal and Nocturnal Arcs of the Heavenly Bodies. The Diurnal Arc of a heavenly body, is that apparent arc which it describes in the heavens, from its rising to its setting.

Describe the three principal aspects. What is the elongation of a planet?

24. What notice did the ancient poets take of the rising and setting of the stars? Describe the achronical rising and setting of the stars, cosmical and heliacal.

25. Describe the diurnal arc of a heavenly body.

The Nocturnal Arc of a heavenly body is the arc which it describes from its setting to its rising.

In reference to the sun, the diurnal arc is described during the day, and the nocturnal arc during the night. The celestial meridian bisects these arcs; hence, when the sun's centre comes to the superior meridian (9) it is apparent noon or Mid-day and when it comes to the inferior meridian, it is mid-night.

26. Apparent Solar, and Mean Solar Time. The Apparent Solar Day is the time which elapses between two consecutive transits of the sun's centre over the same meridian. It is evident that the sun, on account of his irregular motion in longitude and the obliquity of the ecliptic, will come to the meridian at some seasons before, and at others after, a supposed sun comes to it moving in the equinoctial regularly, and according to the sun's mean motion in longitude. Hence a mean between the lengths of all the solar days of the year, is called a Mean Solar Day, and is of uniform duration, being 24 hours long.

The Equation of Time is the difference between apparent and mean solar time, or between apparent and mean noon.

On the 15th April, 15th June, 1st September, and 24th December, the equation of time is zero. It is greatest about 11th February, and 1st November, when the apparent noon at the former date is 14½ minutes slower than mean noon, or 12 o'clock shown by a clock regulated to keep mean solar time, and at the latter date the apparent noon is 16¼ minutes faster than mean noon.

An Astronomical Day consists of 24 hours, and is

Describe the nocturnal arc of a heavenly body. In reference to the sun what are these arcs, and by what bisected? Why is it mid-day and mid-night when the sun comes respectively to the superior and inferior meridian?

26. What is the apparent solar and mean solar day? What is the equation of time, and on what four days of the year is it zero? On what two days is it greatest? What is its amount on these days? What is an astronomical day?

reckoned from noon of the common day, the hours being numbered to 24.

The Civil, or Natural Day consists of 24 hours, but begins differently in different nations. In most of the European nations, and in America, the civil day begins at mid-night.

An Artificial Day is the time which elapses between the sun's rising and setting, and varies in different latitudes.

A Solar, or Tropical Year is the time which elapses between two consecutive returns of the sun to the vernal equinox, and consists of 365d. 5h. 48m. 48s. of mean solar time. This is the true natural year, because it preserves the same seasons in the same months.

27. Siderial Time. A Siderial Day is the time which elapses between two consecutive transits of any fixed star over the same meridian. Or it is the period in which the earth makes one complete rotation on its axis, and consists of 23h. 56m. 4s. of mean solar time, being 3m. 56s. less than 24 hours, the mean solar day. This difference arises from the sun's mean motion in longitude.

The siderial day is the most uniform of all astronomical periods, having undergone, according to the computations of La Place, no change for 2000 years past, and is therefore an essential measure in all astronomical observations.

A Siderial Year is the time which elapses during the sun's apparent motion in the ecliptic from any fixed star, till he returns to the same star again, and consists of 365d. 6h. 9m. 11s., being 20m. 23s. longer than the tropical

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What is a civil or natural day? An artificial day? What is a solar or tropical year, and why called the true natural year?

27. What is a siderial day, and to what period is it equal? How much less is the siderial day than the mean solar day? What is the most uniform of all astronomical periods? What is a siderial year? How long is a siderial year? How much longer is a siderial year than a tropical year?

year; hence, the sun returns to the equinox every year. before he returns to the same point in the heavens; and consequently, the equinoctial points have a slow motion from east to west, called the Precession of the Equinoxes.

28. Zones and Climates. A Zone is a portion of the surface of the earth, bounded by two small circles parallel to the equator. There are five zones, namely, one torrid, two temperate, and two frigid zones.

The Torrid Zone extends from the tropic of Cancer to the tropic of Capricorn, being 46° 56′ broad.

The two Temperate Zones are each 43° 4′ broad. 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.

The two Frigid Zones are those portions of the earth's surface bounded by the polar circles. The north pole, which is 23° 28′ from the arctic circle, is situated in the centre of the north frigid zone; and the south pole, which is 23° 28′ from the antarctic circle, is situated in the centre of the south frigid zone.

Climate is a small portion of the surface of the earth bounded by two small circles parallel to the equator, and is of such a breadth, that the length of the longest day in the parallel nearest the pole, exceeds the length of the longest day in the parallel next the equator by half an hour in the torrid and temperate zones, and by one month in the frigid zones. Hence, since the length of the longest day at the polar circles is 24 hours, and at the poles 6 months, there are 24 climates between the equator and each polar circle, and 6 between each polar circle and its pole.

What is the consequence of this difference on the equinoctial points, and what called?

28. What is a zone, and how many are there? Describe the torrid zone. The two temperate zones. The two frigid zones. What is climate, and how many are there?

29. Inhabitants of the Earth peculiarly situated with respect to each other. Antœci are those people who live under the same meridian, and in the same degrees of latitude, but the one north and the other south latitude. They have contrary seasons of the year.

Periœci are those who live in the same parallel of latitude, but in opposite longitudes. They have the same seasons of the year, but, when it is noon with the one, it is midnight with the other.

Antipodes are those inhabitants who walk feet to feet, or diametrically opposite to each other. Their latitudes, longitudes, seasons of the year, and hours of the day, are all contrary to each other.

CHAPTER II.

ASTRONOMY—MOTIONS AND POSITIONS OF THE SUN, MOON, AND PLANETS.

30. Astronomy. Astronomy is that science which treats of the motions, positions, connexions, periods, distances, phenomena, and magnitudes of the heavenly bodies. It is usually divided into Descriptive, Physical, and Practical Astronomy.

Descriptive Astronomy comprises an account of the motions, positions, appearances, &c. of the heavenly bodies; Physical Astronomy applies the principles of Mechanics in the investigations of the causes of their motions; and Practical Astronomy is that branch of the science which treats of the description and use of astronomical instruments, the method of determining the distances and

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29. What inhabitants of the earth are called Antœci? What, Periœci? What, Antipodes?

30. What is astronomy, and how usually divided? What does descriptive astronomy comprise? What is physical astronomy? Of what does practical astronomy treat?

magnitudes of the heavenly bodies, and their position in space.

31. Pythagorean System. The real motions and positions of the sun, moon, and planets, were the subjects of conjecture and dispute among astronomers of former and ancient times. The wise Samian philosopher, Pythagoras—who flourished more than 500 years before Christ—taught that the sun was the centre, round which the planets that were then known, revolved in the following order:—Mercury, Venus, the Earth, Mars, Jupiter, and Saturn. This system—afterwards demonstrated to be true, but being contrary to the prejudices of sense and opinion—was in later times lost, and succeeded by another, taught by Ptolemy.

32. Ptolemean System. Ptolemy, an Egyptian philosopher, who flourished in the beginning of the second century of the Christian era, supposed the earth to be fixed, and the sun, moon, and planets to revolve round it.

In order to account for the direct and retrogade motions and stationary appearance of a planet, Ptolemy supposed it to revolve in an epicycloid, which is a curve generated by the revolution of the periphery of a circle about the convex or concave side of the periphery of another circle. This system prevailed until near the middle of the sixteenth century.

33. Copernican System. At length, the famous Polish philosopher, Nicolaus Copernicus, who was born at Thorn, in 1473, restored the Pythagorean system, and published his views on that interesting subject in 1530; but, the learning of the times, and the false notions that then prevailed, were by no means favorable to the reception and propagation of a philosophy so sublime and refined.

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31. Describe the Pythagorean system. How early was this system taught, and by whom? Was this system in later times lost?

32. What did Ptolemy suppose? How did he endeavor to account for the direct and retrograde motions, and stationary appearance of a planet? How long did this system prevail?

33. Who restored the Pythagorean system? When did Copernicus publish his views on this subject?

The Copernican system,—so called on account of its celebrated author, for such he may be considered,—regards the sun as its centre, with all the planets revolving round him from west to east, in elliptical orbits, at different distances and in different periods of time. Those planets which are near the sun, move faster in their orbits, and perform their circuits sooner, than those more remote. The truth of this system has been confirmed by the astronomical observations of the most celebrated philosophers that have lived since the time of Copernicus, as, Kepler Galileo, Descartes, Gassendus, Newton, and La Place No astronomical phenomenon, inconsistent with it, i known to exist. Astronomers therefore adopt it as the true system.

34. Tychonic System. Tycho Brahe, a Dane, and eminent philosopher, endeavored to support another system; and, towards the close of the sixteenth century, made known to the literary world an hypothesis of his own. In this system the earth is made the centre, and the sun and moon to revolve round it every 24 hours; the planets Mercury, Venus, Mars, &c. to revolve round the sun.

Some of Tycho's disciples maintained, that the diurnal motion of the heavenly bodies arose from the rotation of the earth on its axis; and that the sun, with all the above planets revolving round him, moved round the earth in a year. This hypothesis, partly true and partly false, gave place to the only true system taught so early by Pythagoras, and his disciple Philolaus, and, after the lapse of more than 2000 years, restored by Copernicus.

35. Solar System. The sun and all the bodies connected with him,—as the planets with their satellites, and comets,—constitute the solar system.

Why called the Copernican system? Give a particular description of it. By whom confirmed?

34. What system did Tycho Brahe endeavor to support What were the views of some of Tycho's disciples?

35. What bodies constitute the solar system?

36. Planets, and their Order. The planets—including the earth, and those discovered since the time of Copernicus—with their satellites, move round the sun in the following order with regard to their distances from him: Mercury, Venus, the Earth, Mars, the Asteroids (or the following nine small planets, namely, Vesta, Juno, Ceres, Pallas, Astræa, Hebe, Flora, Iris, and Metis,) Jupiter, Saturn, Uranus, and Neptune. Mercury and Venus are called inferior, or rather, interior planets, because their orbits are within the orbit of the earth; the others are called superior or exterior planets.

CHAPTER III.

KEPLER'S LAWS, AND THE THEORY OF GRAVITATION.

37. Kepler's Laws. John Kepler, a celebrated German astronomer, about the beginning of the seventeenth century, made the following very important discoveries:

1. That the orbit of the earth, or any planet, is an ellipse, of which the sun is placed in one of the foci.

2. That the straight line, called the Radius Vector, which joins the centre of the sun and the centre of the earth or planet at any time, describes areas proportional to the times.

3. That the squares of the periodic times of the earth and planets, are proportional to the cubes of their mean distances from the sun, or to the cubes of the semi-major axes of their orbits. These laws of the earth, and planets

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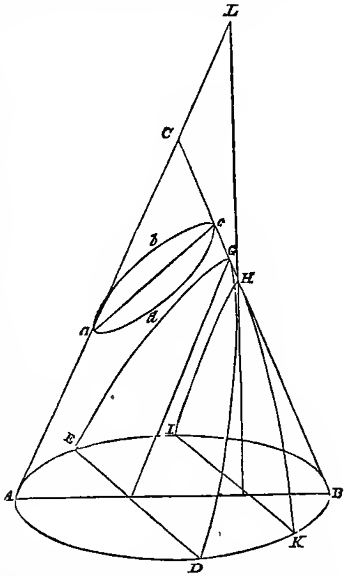
36. Describe the motion of the planets, and their order. What are Mercury and Venus called, and why? What, the others?

37. Who was John Kepler, and when did he make some important discoveries in relation to the motions of the earth and planets? Repeat his first law. The second. The third.

in their motions, have therefore been denominated Kepler's Laws.

Other astronomers since Kepler's time have not only verified these laws of the planetary motions, but have found that the satellites, in their revolutions round their primaries (21) are subject to the same laws.

The orbits of many of the comets are so very eccentric, as not to differ sensibly, in that part of their visible orbits, from Parabolas. Some are said to describe Hyperbolas in their course. These three figures, namely, the ellipse, the parabola, and the hyperbola, are called the Three Conic Sections.



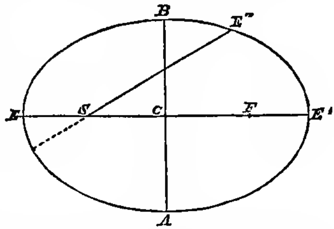
Let A B C represent a right cone, having for its base the circle A D B E; and let it be cut by the plane *a b c d* obliquely to the base, and passing through the opposite slant sides of the cone A C, B C; then the curve *a b c d*, which is formed by the intersection of this plane and the surface of the cone, is called an Ellipse.

Again: let the cone be cut by the plane E G D, perpendicular to the plane A B C, and parallel to the slant side A C; then the curve formed by this plane and the surface of the cone, is called a Parabola. But, if the plane H I K, as before, perpendicular to the plane A B C, cut the cone, so as to meet the slant side A C, produced in the direction C, in L; then the section I H K is called an Hyperbola.

What have other astronomers since Kepler's time, done? What is said of the orbits of many of the comets? Draw the diagram, and describe the curves called the Three Conic Sections.

38. **Kepler's First Law.** Kepler first discovered that the orbit of Mars was an ellipse; and, after pursuing his investigations, arrived at the same conclusion with regard to the orbits of the earth and the other planets.

Let E A E′ B represent the earth's orbit, and S the sun. From a series of observations made throughout the year, it has been found, that when the sun's apparent diameters were the least and the greatest, his longitudes at these times differed 180°; hence the two lines joining these longitudes and the sun, will be one straight line as E S E′; and the distances E S and E′ S will be inversely proportional to the sun's apparent diameters, when viewed from the points E and E′ of the earth's orbit; because the different distances at which any object is viewed, are inversely proportional to its apparent dimensions at these distances.



Let d = sun's greatest apparent diameter.
" d' = " least do. do.
" d'' = " apparent diameter at any intermediate point, as E″.

Now, from a series of intermediate apparent diameters and corresponding longitudes, it has always been found that—

$$d'' = \frac{d + d'}{2} - \frac{d - d'}{2} \cos. E' S E'',$$

the angle E′ S E″ being equal to the difference of the sun's longitudes at E′ and E″, or any intermediate point between E′ and E. From this equation the property of the curve E′ E″ E may be deduced, which will be found the same as that of an ellipse.

Bisect E E′ in C, and through C draw A B perpendicular to E E′, and take C F equal C S. Now, from the relation

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38. What did Kepler first discover? After pursuing his investigations, at what conclusion did he arrive? Draw the Diagram, and explain on what principle the property of the elliptic curve may be deduced.

between the sun's distances and his apparent diameters, we have—

$$E'S : ES :: d : d',$$

and $$E'S : E'S \pm ES :: d : d \pm d';$$

therefore $$E'S : EC :: d : \frac{d + d'}{2} = \frac{EC}{E'S} d,$$

and $$ES : SC :: d : \frac{d - d'}{2} = \frac{SC}{E'S} d.$$

Also $$E''S : ES :: d : d'' = \frac{ES}{E''S} d.$$

By substituting these values in the equation—

$d'' = \frac{d + d'}{2} - \frac{d - d'}{2}$ *cosin* E′ S E″, and dividing by d, we have—

$$\frac{ES}{E''S} = \frac{EC}{E'S} - \frac{SC}{E'S} \text{ cosin } E'SE'',$$

and $ES \times E'S = (EC - SC) \times (EC + SC)$ (for $EC = E'C$) $= EC^2 - SC^2 =$
$E''S\,(EC - SC \text{ cosin } E'SE'')$; hence,

$$E''S = \frac{EC^2 - SC^2}{EC - SC \text{ cosin } E'SE''}.$$

This is the polar equation of an ellipse, having the pole at S.

The line E E′ is called the major, and A B the minor axis of the ellipse. These lines are also called the transverse and conjugate axes. C is the centre, and the points S and F are the two foci. The line S E″, which joins the sun and the earth or planet in any part of its orbit, is called the radius vector. The distance C S or C F, between the centre and either focus, is called the eccentricity of the ellipse or orbit, and is generally expressed in parts of the semi-transverse axis regarded as a unit.

That point of a planet's orbit as E, which is nearest to the sun, is called the Perihelion; and that point which is most distant, as E′, is called the Aphelion. The corresponding

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What are the major and minor axes? What also called? Describe the two foci and the radius vector. What is the eccentricity of the ellipse, and in parts of what, regarded as a unit, expressed? What points of a planet's orbit are called the perihelion and aphelion?

points of the moon's orbit, or the apparent orbit of the sun, are called Perigee and Apogee. These points are also called Apsides,— the one nearest to the earth, the Lower Apsis, and the one farthest from it, the Higher Apsis. The line joining these is called the Line of the Apsides.

39. KEPLER'S SECOND LAW. The sun's apparent motion in longitude, or the earth's real motion in its orbit, varies at different times of the year. Thus when the sun's apparent diameter is the least, which is about the 1st of July, and consequently, the earth is then in the aphelion at E, the sun's daily apparent motion in longitude or angular velocity, will also be the least, namely, 57′ 11″ in a mean solar day. But when the sun's apparent diameter is the greatest, which is about the 1st of January, the earth being then in the perihelion at E′, the daily motion in longitude will also be the greatest, namely, 61′ 10″. It is also found that the daily motions of the sun in longitude throughout the year are proportional to the squares of the corresponding apparent diameters; but the apparent diameters are inversely proportional to the radii vectores; therefore the sun's apparent daily motions, or the earth's real motions, are inversely proportional to the squares of the radii vectores or distances.

Suppose the earth to pass over the portion $a\ b$ of its orbit in some small period of time. Take e, the middle point of $a\ b$, and with S as a centre, and the radius vector S e as a radius, describe the arc $c\ d$, and with S D equal the mean distance or unity, describe the arc $f\ g$. It is evident that $a\ b$ may be so small, that the elliptical sector S $a\ b$ will not sensibly differ from the circular sector S $c\ d$. Put the distance of the earth at e, or the radius vector $= r$, and the angle a S b measured by $f\ g$, the angular velocity for the short period of time $= v$. Now, because the circular sectors S $f\ g$ and S $c\ d$ are similar,

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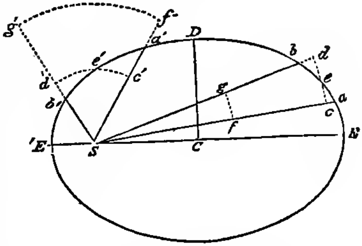
What are the corresponding points in the moon's orbit, or the apparent orbit of the sun, called? What also called?

39. When has the sun the least apparent diameter, and when the greatest? What is the sun's apparent daily motion in longitude, or angular velocity, at these times? To what are the daily motions of the sun throughout the year proportional? And to what inversely proportional?

we have sector S f g : sect. S c d :: S f^2: S c^2, or S f g: S c d :: 1 : r^2, S f, being $= 1$; hence S c d $=$ S f g $\times$ r^2 but S f g $= \frac{1}{2} f\, g \times$ S $f = \frac{1}{2}\ v$; therefore S c d or the elliptical sector S a b $= \frac{1}{2}\ v\ r^2$.



Again, if we suppose the earth to pass over another portion of its orbit a' b' in the same small period of time, and calling r' and v' the radius vector and angular velocity, we shall also have the elliptical sector S a' b' $= \frac{1}{2}\ v'\ r'^2$. But v : v' :: r'^2 : r^2; hence $v\ r^2 = v'\ r'^2$, or $\frac{1}{2}\ v\ r^2 = \frac{1}{2}\ v'\ r'^2$; therefore S a b $=$ S a' b'; that is, the radius vector describes equal areas in equal times, and consequently areas proportional to the times, which is Kepler's second law.

40. Kepler's Third Law. Kepler obtained his third law by comparing the periodic times of the planets and their mean distances from the sun. From these comparisons he found that the squares of the periodic times are proportional to the cubes of their mean distances, or to the cubes of the semi-major axes of their elliptic orbits. This law prevails among the satellites of each secondary system, namely, that the squares of the times of their revolutions round the primary, are proportional to the cubes of their mean distances from that body regarded as their centre of motion.

41. Attraction of Gravitation. That force by which bodies near the surface of the earth are incessantly impelled towards its centre, is called Gravity, or the Attraction of Gravitation. This attractive force is mutual

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Draw the Diagram, and prove that the radius vector describes areas proportional to the times.

40. How did Kepler obtain his third law? What did he find from these comparisons? Does this law prevail among the satellites of each secondary system?

41. What is gravity, or the attraction of gravitation?

among the particles of matter, and belongs to all bodies in the universe; therefore it is called the principle of Universal Gravitation.

The planets are retained in their orbits by the attractive force of the sun, which is called the Solar Attraction; and the planets are endued with the same power in attracting the sun and each other. The satellites are also retained in their orbits by the attractive force of their respective primaries.

To apply the laws of universal gravitation, as established by the principles of Mechanics, in the investigation of the motions of the heavenly bodies, is an extensive and difficult science. This branch of our subject, called Physical Astronomy, will be found discussed at length in La Place's *Mécanique Céleste* and other similar works. The following elementary propositions are all that can be here introduced.

42. The Force of Attraction varies directly as the Mass. From the motions produced by the action of the sun and planets upon each other, it is found that the force of attraction in these bodies, is directly proportional, at the same distance, to their respective masses. It is also known, that the force of attraction in several bodies, at the same distance, for another body, is proportional to the mass of those bodies. Hence the force of attraction of one body for another, varies as the number of similar attracting particles, or mass, of that body.

43. The Force of Attraction varies inversely as the Square of the Distance. From the principle here laid down, Kepler's laws respecting the planetary motions and periods can be established. But by assuming

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Why called the principle of universal gravitation? By what force are the planets retained in their orbits? Do the planets attract the sun and each other? By what force are the satellites retained in their orbits? What is said of the application of these laws in the investigation of the motions of the heavenly bodies?

42. To what is the force of attraction of the sun and planets, at the same distance, proportional?

43. How does the force of attraction of the same body at different distances vary? How can this principle be established?

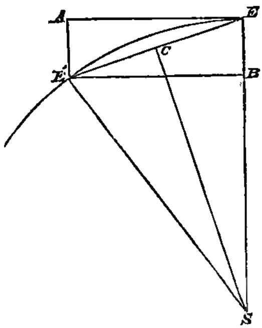
this principle not to be true, a result would be obtained contrary to these laws, which have been confirmed by actual observations; therefore it follows that the proposition must be true.

The theory of gravitation as stated in the last and present articles, namely, that *the force of attraction varies directly as the mass, and inversely as the square of the distance,* was first promulgated by Sir Isaac Newton; and hence it is sometimes called, The Newtonian Theory of Gravitation.

44. CENTRIPETAL AND PROJECTILE FORCES. That force continually impelling a body towards the sun, or centre around which it revolves, is sometimes called the Centripetal Force; and that force which causes it to recede from that centre, is called the Centrifugal, or Projectile Force.

The nature of the orbit will depend on the *intensity* of the projectile force. Thus a certain intensity of force will produce a parabola; a less intensity, an ellipse or circle; and a greater, an hyperbola.*

45. QUANTITIES OF MATTER IN THE SUN AND PLANETS, OR THEIR RELATIVE MASSES.



Let S represent the sun, and E E' that portion of the earth's orbit, regarded as circular, described in one second of time. Draw E A tangent to the orbit at E, and from E' draw E' A and E' B respectively perpendicular to E A and E S. Also draw the chord E E' and S C perpendicular to it at the middle point C.

According to the first law of motion, if the projectile force acted alone, the earth would be carried from E to A in one second of time; but the earth is at E'; therefore A E', or its equal E B, is the distance

* Norton's Astronomy, Article 624.

44. Describe the centripetal and projectile forces. On what will the nature of the orbit depend?

the earth has been drawn in one second of time by the attractive force of the sun at S. And as the distance through which a body moves in a given time is proportional to the force by which it is impelled, the versed sine E B of the arc E E′ will measure the attractive force by which the earth is drawn towards the sun.

Put D = E S the mean distance of the earth from the sun;
F = E B the attractive force of the sun;
P = the earth's periodic time in seconds;
1 = the mass of the sun;
m = the mass of the earth;
π = the ratio of the diameter to the circumference of the circle;

hence $\frac{2\ D\ \pi}{P}$ = the arc E E′, which does not sensibly differ from the chord E E′.

In the similar triangles S C E and E E′ B, we have—
S E : C E :: E E′ : E B, and 2 S E : 2 C E :: E E′ : E B,

$$\text{or } 2\ D : \frac{2\ D\ \pi}{P} :: \frac{2\ D\ \pi}{P} : F = \frac{2\ D\ \pi^2}{P^2}.$$

By putting f = the attractive force by which the moon is drawn towards the earth, d = the mean distance of the moon, and p = the moon's siderial revolution in seconds; we will find in like manner $f = \frac{2\ d\ \pi^2}{p^2}.$ Now, since these forces F and f are to each other directly as the masses of the sun and earth, and inversely as the squares of the distances of the earth from the sun, and of the moon from the earth (42, 43), we have—

$$F : f :: d^2 \times 1 : D^2 \times m,$$

$$\text{or } \frac{2\ D\ \pi^2}{P^2} : \frac{2\ d\ \pi^2}{p^2} :: d^2 : m\ D^2 = \frac{d^3}{p^2} \times \frac{P^2}{D}; \text{ hence,}$$

$$m = \frac{d^3}{p^2} \times \frac{P^2}{D^3} = \left(\frac{d}{D}\right)^3 \times \left(\frac{P}{p}\right)^2.$$

Which formula, by substitution, will give the earth's relative mass, that of the sun being = 1. This formula will also serve for computing the mass of any of the planets that have satel-

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45. Draw the diagram, and show how the relative masses of the sun and planets that have satellites, are determined.

lites, by using the planet's distance, and that of either of its satellites, in the first factor; and the planet's period, and that of the satellite, in the other.

The mass of a planet which has no satellites, and that of the moon, can only be found from the observed amount of perturbations produced by their action, in the motions of the other heavenly bodies.

46. Densities of the Sun, Moon, and Planets. The densities of two bodies of equal masses are to each other inversely as their volumes or magnitudes; and the densities of two bodies of equal volumes are to each other directly as their masses. Let M and m represent the masses of two bodies, and V and v their respective volumes. Then if their masses be equal, their densities will be as $v : V$, or as $\frac{1}{V} : \frac{1}{v}$; but M and m being their masses, their densities will be as $\frac{M}{V} : \frac{m}{v}$. That is, the densities of bodies are proportional to their masses divided by their volumes.

CHAPTER IV.

DIP OF THE HORIZON, ASTRONOMICAL REFRACTION, TWILIGHT, HEIGHT OF THE ATMOSPHERE, AND PARALLAX.

47. Dip of the Horizon. Let E represent the place of the observer's eye, at the distance of e E above the earth's surface, and S any heavenly body. Draw the tangents E H and $e\ h$, which will respectively represent the visible horizons (8) at E and e. Draw E H′ parallel

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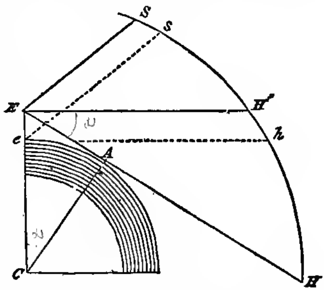
How can the masses of the planets that have no satellites, and that of the moon, be determined?

46. How do the densities of two bodies of equal masses vary? How do the densities of two bodies of equal volumes vary? Prove that the densities of two bodies are proportional to their masses divided by their volumes.

to *e n*, and *e s* parallel to E S, and join C the centre of the earth, and A the point of tangency of E H. When the body S is viewed from E and *e*, the lines of vision E S and *e s* will be parallel, on account of the very small elevation *e* E compared with the great distance E S; hence the angle S E H′ is equal to the angle *s e h*. Now the angle S E H is the observed altitude of S when viewed from E, and *s e h* is the altitude when viewed from *e*; but we have S E H — H E H′ = S E H′ = *s e h*; therefore we must subtract from the observed altitude the angle H E H′, called the Dip or Depression of the Horizon, in order to obtain the apparent altitude.



Because the sum of the angles C + C E A is equal to a right angle, and consequently equal to the right angle C E H′; take from each C E A, and there remains C = H E H′. Put *e* E = *h*, and C A or C *e*, the radius of the earth = *r*; and we have—

E A $= \sqrt{(r + h)^2 - r^2}$ = the distance to which a person can see on the earth at an elevation equal to *h*. The angle C, or the dip of the horizon, is found for various elevations by the following proportion:

C E : C A : : Radius : *cosin* C, or

$r + h$: r : : R. : *cosin* C, and the results entered in a table, called a Table of the Dip of the Horizon.

48. Astronomical Refraction. It is an established fact in Optics, that a ray of light in passing *obliquely* out of a vacuum into a transparent medium, or out of a

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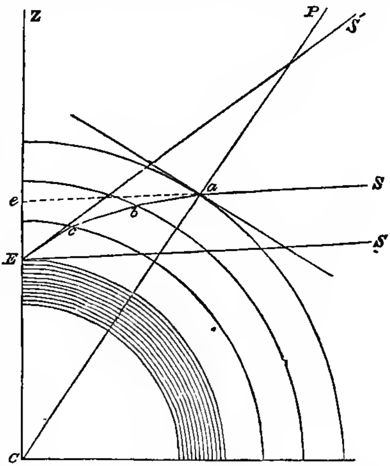
47. Draw the diagram, and explain fully what is understood by the dip of the horizon. How is the apparent altitude obtained? How is the distance obtained to which a person can see at a certain elevation? How is the dip of the horizon obtained for various elevations?

rarer into a denser medium, will become bent or *refracted* towards a perpendicular at the incident ray. Now, since the earth is surrounded by an atmosphere which gradually decreases in density, as the distance from the surface increases, the rays of light in proceeding from the heavenly bodies into the atmosphere, and thence from one stratum of atmosphere into another, will become gradually refracted towards the radius drawn from the centre of the earth to the point of incidence.

Thus let S *a* represent a ray passing from S and entering the atmosphere at *a;* instead of passing on in the straight course *a e*, and over the head of an observer at E, it will be refracted towards the perpendicular P C as it enters the different strata of the atmosphere, in the broken line *a b c* E to his eye. But since the number of strata is infinite, or which is the same thing, the density of the atmosphere gradually increases, by infinitely small degrees, from *a* to the surface, the number of deflections will be infinite, and the broken line *a b c* E will become a curve concave towards the earth's surface. The tangent E S′ to the curve *a b c* E at E, will point out the direction in which the ray enters the eye at E, and represent the position of the heavenly body S more elevated as at S′. Draw E S parallel to



48. When does a ray of light become refracted, and towards what? Towards what will the rays of light be gradually refracted, in passing through the different strata of the atmosphere? Draw the diagram, and

e S, and the angle S E S′ will be the increase in altitude produced by atmospherical refraction, called *astronomical refraction*, or simply *refraction*. Hence the refraction must be *subtracted* from the observed altitude, and *added* to the observed zenith distance.

49. AMOUNT OF REFRACTION. It is also according to an established principle in Optics, that the more obliquely a ray of light passes from a rarer into a denser medium, the greater is the refraction; hence the refraction of the heavenly bodies is greatest when they are in the horizon, and decreases with the increase of altitude to the zenith.

Mathematicians, by persevering investigations, have obtained formulæ by which the astronomical refraction may be found for different altitudes from the horizon to the zenith. These formulæ have been proved correct by the observations of astronomers, except for altitudes under 10°. In such low altitudes the refraction is irregular and uncertain. From these formulæ tables of refraction have been computed, adapted to the mean state of the atmosphere, namely, when the barometer stands at 30 inches and the thermometer at 50°. These are called *mean refractions*. To these tables, columns are annexed, containing the corrections to be applied to the mean refractions, for the existing state of the atmosphere at the time of observation.

The amount of refraction in the horizon is about 34′; at an altitude of 45°, it is about 58″; and in the zenith it is zero, since the rays of light from that point enter and pass through the atmosphere perpendicularly.

50. EFFECTS OF REFRACTION. The stars and the centres of the sun and moon appear in the horizon by

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show how the altitude of a heavenly body will be increased by atmospherical refraction.

49. What effect has the obliquity of a ray, in passing from a rarer into a denser medium, on its refraction? Where is refraction the greatest? To what state of the atmosphere are tables of refraction adapted, and what are such refractions called? What is the amount of refraction in the horizon? At an altitude of 45°? In the zenith?

the effects of refraction, when they are really 34′ below it; hence the refraction accelerates the rising of the heavenly bodies, and retards their setting. Having this effect in rendering the sun longer visible, the length of the day will thereby be increased. Since the apparent diameter of the sun or moon is something less than 34′, the horizontal refraction, it follows that the discs of these bodies (21,) about the time of rising or setting, may be wholly visible, when they are actually below the horizon.

The discs of the sun and moon, when near the horizon, appear somewhat elliptical, because the lower limb of either of these bodies in that situation, is more elevated by refraction than the upper, and in consequence of which, the vertical diameter appears shortened, while the horizontal diameter remains unaffected. In the horizon, the vertical diameter is about one-eighth less than the whole diameter.

Refraction, also, by elevating two heavenly bodies in vertical circles (11) which meet in the zenith, makes their apparent distance less than their true distance.

51. Twilight, or Crepusculum. Twilight is that faint light which we perceive for some time before the sun rises and after he sets. It depends both on the refraction and reflection of the sun's rays in the atmosphere. Twilight begins in the evening when the sun sets, and gradually decreases till he is 18° below the horizon, when it ends. It also begins in the morning, or it is *daybreak*, when the sun is within 18° of the horizon, and gradually increases till sunrise.

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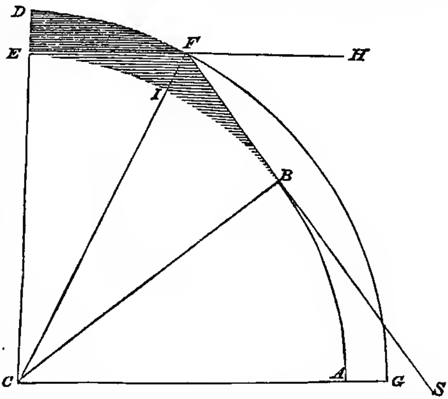
50. What effect has refraction on the rising and setting of the heavenly bodies? What on the length of the day? What effect on the sun and moon, when their upper limbs touch the horizon? Why do the discs of the sun and moon, when near the horizon, appear elliptical? Why is the apparent distance of two heavenly bodies less than their true distance?

51. What is twilight, and on what does it depend? When does it begin, and when end?

52. Height of the Atmosphere.

From the datum stated in the last article, we are enabled to find at what height the atmosphere ceases to reflect the sun's rays.

Thus let A B E represent a portion of the surface of the earth, D F G the surface of the atmosphere above it, and E F H he visible horizon touching the earth at E, the place of the observer, and intersecting the surface of the atmosphere at F. Then another line F B S drawn from F, touching the earth in B, will be the direction of the sun when the twilight ceases, and consequently, according to observation, will make with the horizon the angle H F S = 18°. From the points B, E, and F, draw to the centre C, the lines B C, E C, and F C, the latter meeting the earth in I.



Now it is evident, by inspecting the figure, that the highest particle of the atmosphere at F, supposed capable, will reflect the light in the direction F E; hence none of that part of the atmosphere D E F above the horizon will be illuminated, and consequently twilight will end at E. The part E I B F, though not directly enlightened by the sun, receives a degree of light by reflection from that part of the atmosphere on which he shines.

Because the two angles E and B of the quadrilateral E C B F are right angles, the other two E C B and E F B will be together equal to two right angles; therefore E C B = H F S = 18°, and E C F = 9°. Then—

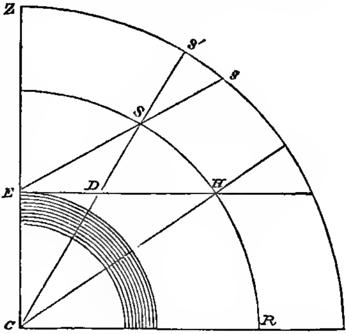
52 From the datum, namely, that twilight ceases when the sun is 18° below the horizon, find at what height, by drawing the diagram and working the problem, the atmosphere ceases to reflect the sun's rays.

as	*cos.* E C F 9° ar. co.	. . . . . .	0.0053801
is to	Radius	. . . .	10.0000000
so is	E C 3956*m.*	. . . .	3.5972563
to	C F 4005*m.*	. . . .	3.6026364

Hence C F — C I = I F = 4005*m.* — 3956*m.* = 49 miles the height of the atmosphere.

53. Parallax. That place in the heavens in which any celestial body appears to an observer on the surface of the earth, is called its *apparent* place; and that place in which it would appear at the same time to an observer at the centre of the earth, is called its *true* place. The difference between its true and apparent place is called the *Parallax.* Astronomers find it convenient in their computations to reduce the apparent places of the heavenly bodies to their true places.

Let S represent any heavenly body, E the place of an observer on the surface of the earth, and C its centre At E, the body S would appear as at *s* in the celestial sphere, its apparent place when corrected for dip of the horizon (47) and refraction (48): and at C it would appear as at *s'*, its true place. The angle E S C or *s* S *s'* is the difference between the true and apparent place of the body S, called its parallax, and is the angle which the earth's radius subtends by two imaginary straight lines drawn from the centre of the body, one to the place of observation on the surface of the earth, and the other to its centre. When the body S is above the sensible



53. What is the apparent place of a celestial body? What is its true place? What is the difference between its true and apparent place called? Draw the diagram, and show what angle is the parallax.

horizon E H (8), the angle E S C is called the *parallax in altitude;* and when it is in the horizon at H, the angle E H C is called the *horizontal parallax.* If the place of observation be on the equator, the horizontal parallax is called the *equatorial parallax.*

The angle S E H is the observed altitude of the body S in regard to the sensible horizon E H, and the angle S C R the true altitude in regard to the rational or true horizon C R; but because of the parallels E H and C R, the angle S C R = S D H = S E H + E S C: hence the true altitude is obtained by *adding* the parallax in altitude to the observed altitude.

54. Parallax in Altitude.

Put H = the horizontal parallax, p = the parallax in altitude, and Z = the observed zenith distance (19) of the heavenly body. Then in the triangle S E C (see last fig.) we have S C : E C : : sin. S E C = sin. S E Z = sin. Z : sin. E S C = sin. p; and in the triangle H E C, we have H C = S C : E C : : Radius: sin. E H C = sin. H; therefore, sin. Z : sin. p. : : 1 : sin. H, taking radius equal to unity; hence—

$$\sin. p. = \sin H \ . \ \sin Z.$$

Since the parallax is always a very small angle, we may substitute the arc instead of the sine, so that the above equation becomes—

$$p = H \ \sin. \ Z.$$

Hence the parallax in altitude varies as the sine of the zenith distance, or as the cosine of the observed altitude, and equals the product of the horizontal parallax by the sine of the apparent zenith distance.

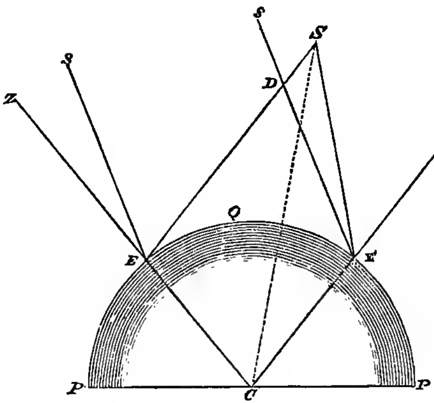
From this equation we see that when the body is in the zenith, the parallax = 0; also, that when the zenith distance is 90°, or when the body is in the horizon, the parallax is a maximum.

What is parallax in altitude? Horizontal parallax? Equatorial parallax? How is the true altitude obtained?

54. Demonstrate that the parallax in altitude varies as the sine of the zenith distance. To what is the parallax in altitude equal? When is the parallax zero, and when a maximum?

55. Horizontal Parallax.

Let E and E′ represent the places of two observers on the same terrestrial meridian (9) E Q E′ 80° or 90° remote from each other, S a heavenly body, the horizontal parallax of which is to be found, and *s* a fixed star, which comes to the meridian at nearly the same time with the body S. Let the observers at the same time find the meridian zenith distances Z E S and Z E′ S corrected for refraction, and the meridian zenith distances Z E *s* and Z′ E′ *s* also corrected for refraction.



Put the angle S E *s*, the difference between the zenith distances of S and *s*, as observed at E, $= d$; S E′ *s*, the difference between the zenith distances of the same bodies, as observed at E′, $= d'$; and the parallaxes in altitude E S C and E′ S C respectively $= p$ and p'. The angle E S E′ $=$ E D E′ — S E′ *s* $=$ S E *s* — S E′ *s* $= d - d'$, because the lines E *s* and E′ *s* are sensibly parallel on account of the immense distance of the star *s*; and E S E′ $=$ E S C $+$ E′ S C $= p + p'$, but $p + p' =$ H. sin. Z $+$ H. sin. Z′ by the last article; hence H sin. Z $+$ H sin Z′ $= d - d'$, or—

$$H = \frac{d - d'}{\sin. Z + \sin. Z'}$$

By means of this formula, the horizontal parallaxes of the sun and planets may be found. In regard to the parallax of the moon, it will be necessary that the spheroidal figure of the earth be taken into account.

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55. Draw the diagram, and show how the horizontal parallax of a heavenly body may be found. In regard to the parallax of the moon, what is observed?

The sun's parallax, by the foregoing process, may be found within 1″ or 2″ of the truth. By means of a more accurate method, namely, the transit of Venus, Professor Encke, of Berlin, has found the sun's mean horizontal parallax to be 8″.5776.*

From repeated observations made on the moon, her parallax not only varies during one revolution round the earth, but also from one revolution to another. The greatest and least equatorial parallaxes are respectively 61′ 29″ and 53′ 51″ (53). Her mean equatorial parallax is 57′ 1″. The horizontal parallax of Venus, the nearest planet, is 31″, and the parallaxes of the other planets are less in proportion as their distances are greater. The fixed stars have no sensible parallax, on account of their very great distance.

CHAPTER V.

THE SUN.—☉

56. Remarks. The sun, the fountain of light and heat of the whole system, is situated near the common centre, or in one of the foci, of the orbits of all the planets. Besides the sun's apparent diurnal motion, rising in the east and setting in the west, he has an apparent annual motion among the fixed stars. If we observe the positions of some particular groups of stars after sun-set, and at intervals continue our observations for several weeks or months, we will find that the sun will continue to approach

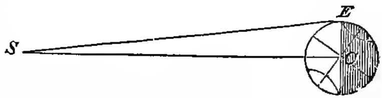
* Gummere's Astronomy, Article 307.

By means of a more accurate method, what has the sun's mean horizontal parallax been found to be? How much is the mean equatorial parallax of the moon? How much is the horizontal parallax of Venus? Why have the fixed stars no parallax?

56. Where is the sun situated with regard to the orbits of all the planets? What apparent motion has the sun?

those stars, and finally he will appear east of them, and thus, in the course of a year, complete his apparent annual progress in the heavens. Hence the position of the fixed stars in the visible heavens, at the same hour of the evening, varies at different seasons of the year.

57. Distance. Perhaps no problem appears more paradoxical and difficult than that of determining the distance of the sun from the earth to a near degree of exactness. From the mean parallax the mean distance is determined. The mean horizontal parallax of the sun, as deduced from the most accurate observations made on the transits of Venus in the years 1761 and 1769, has been found to be 8″.5776 (55). Hence the sun's distance is found as follows:



In the right-angled triangle, E C S right-angled at C; put E C the earth's semi-diameter = r = 1; the angle E S C the mean horizontal parallax = H; and we have—

as sine H, 8″.5776 ar. co.	4.3817894
is to Radius, 90°	10.0000000
so is r, 1	0.0000000
to S E, 24087.3 r	4.3817894

Or, since the circumference of the circle contains 360° = 1296000″, we have 3.1416* : ½ :: 1296000″ : 206264″ = the length of the radius expressed in seconds. And because the parallax is a very small angle, it may be used instead of its sine, without material error. Thus H : Radius : : r : S E, or—

$$\text{S E} = \frac{\text{Radius}}{\text{H}} r = \frac{206264''}{8''.5776} r = 24047\, r \text{ nearly.}$$

* This number expresses the approximate ratio of the circumference of the circle to the diameter.

In what time does the sun make his apparent circuit among the fixed stars? What is the consequence of this apparent motion of the sun?

57. How is the mean distance of the sun determined? Draw the diagram, and show how the distance may be found. Give the other method of finding it.

Taking 3956 miles = the earth's semi-diameter or mean radius, we have 24047 × 3956 = 95,129,932 miles, the mean distance of the sun from the earth.

58. Apparent Diameter and Magnitude. The sun's apparent diameter at his mean distance, is 32′ 1″.8, which is determined by measurements with an astronomical instrument called a Micrometer, or Heliometer. It is evident that the earth's mean horizontal parallax, as seen from the sun, will be equal to 16′ 0″.9, the sun's apparent semi-diameter; and the earth's apparent semi-diameter, as also seen from the sun, will be equal to 8″.5776, the sun's mean horizontal parallax.

Let R = the sun's real semi-diameter,
r = " earth's do.
H = " sun's mean horizontal parallax,
and h = " earth's do.

Then, by the preceding article, the distance—

$$S\,E = \frac{\text{Radius}}{H} r, \text{ and also } S\,E = \frac{\text{Radius}}{h} R;$$

$$\text{hence } R\,H = r\,h, \text{ and regarding } r = 1,$$

$$\text{we have } R = \frac{h}{H} = \frac{16'\ 0''.9}{8''.5776} = 112.$$

Therefore the sun's real diameter is 112 times the mean diameter of the earth, or 7,912 m. × 112 = 886,144 miles, the sun's real diameter. And 112^3 = 1,404,928, which shows how many times greater the sun's volume is, than that of the earth.

59. Solar Spots. When the sun is viewed by a good telescope, furnished with a colored glass to protect the eye, we frequently discover on his surface dark spots,

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What is the sun's mean distance from the earth in miles?

58. What is the sun's apparent diameter at his mean distance, and how determined? Demonstrate the method of finding how many times greater the sun's real diameter is, than that of the earth. What is the sun's diameter in miles? How many times greater is his volume than that of the earth?

called *maculæ*, of various magnitudes and forms. These spots may sometimes be seen by the naked eye, when the sun is partially obscured by thin clouds, or when he is in or near the horizon. Each spot consists of a dark nucleus, surrounded by an umbra or zone of a fainter shade.

The time of their continuance varies from a few hours t several weeks, during which time some increase, and others diminish in size. Some also divide, and others as it were, burst asunder and then disappear. Sometimes the disappearance of these maculæ is succeeded by *fàculæ* or *luculi*, which are spots brighter than the rest of the sun's disc.

60. THEORY OF THE SOLAR SPOTS. No hypothesis entirely satisfactory has been given of the solar phenomena. The most generally received opinion is, that the sun is an opaque body surrounded by an atmosphere composed of phosphoric or self-luminous clouds; that a solar spot is the dark body of the sun seen through an opening in his luminous atmosphere, and that the umbra is a consequence of the shallowness or gradual shelving in the sides of this opening.

Dr. Brewster, of Edinburgh, has advanced the opinion, that the nucleus, or dark body of the sun, is the "magazine from which heat is discharged; while the luminous, or phosphorescent mantle, which that heat freely pervades, is the region where light is generated." This opinion is consonant with the philosophic fact, that the invisible rays which pervade the solar spectrum, and extend beyond the red rays, have a heating power, and are distinct from those which produce the sense of vision on the human retina.

61. ROTATION OF THE SUN ON HIS AXIS. Since the spots on the sun's surface move across his disc from east

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59. What are the dark spots frequently seen on the sun's surface, called? When can they be seen by the naked eye? Of what does each spot consist? Give a description of their continuance and disappearance. By what is their disappearance sometimes succeeded?

60. What is the most generally received theory of the solar spots? Give Dr. Brewster's opinion. With what is this opinion consonant?

to west, it is inferred that the sun has a rotation on his axis from west to east. It requires 27d. 7h. 37m. for a spot to return to the same position which it formerly occupied; but during this interval of time, the earth has advanced in its orbit nearly one sign, and in the same direction with the spot. Let P = 365d. 6h. 9m. the siderial or periodic revolution of the earth (27), S = the time of the siderial revolution of a spot which is required, S′ = 27d. 7h. 37m. its synodic revolution, and 1 = the circumference of the circle. Then—

$$\frac{1}{P} = \text{the earth's daily progress,}$$

$$\frac{1}{S} = \text{" spot's do.}$$

hence $\frac{1}{S} - \frac{1}{P} = \frac{P - S}{S\,P}$ = the daily gain of a spot on the earth;

and $\frac{S'}{S}$ = the distance in revolutions which a spot makes until it returns to the same position, with regard to the earth, which it formerly occupied. Then we have—

$$\frac{P-S}{S\,P} : 1 \text{ circum.} :: \frac{1}{S} : \frac{P}{P-S} = \frac{S'}{S};$$

$$\text{and } P\,S + S\,S' = P\,S',$$

$$\text{or } S = \frac{P\,S'}{P + S'}.$$

Hence P + S′ : P : : S′ : S, or by substitution, 365d. 6h. 9m. + 27d. 7h. 37m. : 365d. 6h. 9m. : : 27d. 7h. 37m. : 25d. 10h. = the true time of the revolution of a spot, or the time of the sun's rotation on his axis.

As the sun revolves on his axis, his figure is supposed not to be exactly spherical, but a little flatted at the poles like our earth. The sun is also agitated by a small motion round the

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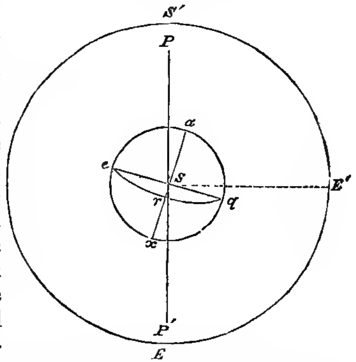
61. How long does it require for a spot to return to the same position which it formerly occupied? From the synodic time of a spot, determine the sun's rotation on his axis.

centre of gravity of the solar system, which is produced by the various attractions of the circumvolving planets.

62. Inclination of the Axis. From the apparent paths of the spots, which are of course parallel to the solar equator, it is deduced that the axis of the sun is inclined in an angle of 7° 20′ to the axis of the ecliptic. At two opposite seasons of the year, June and December, the path of a spot appears as a straight line; but at all other times it will appear as a very eccentric semi-ellipse, which will vary in eccentricity according to the season of the year. It is also found by observations, and computations therefrom, that when the eccentricity of the apparent path of a spot is the least, or when the northern half of the solar axis is inclined towards the earth, and coincides with a plane passing through the centres of the earth and sun perpendicular to the plane of the ecliptic, the sun's longitude is 170° 21′, or 20° 21′ in the sign Virgo. Hence the nodes of the solar equator are 20° 21′ in Gemini and Sagittarius.



Let E represent the earth, *e a q x* the sun's disc, P P′ the axis of the ecliptic, and *a x* the sun's axis perpendicular to the plane of the equator *e q*, and making the angle P S *a* = 7° 20′. When the earth is 20° 21′ in Sagittarius at E, the sun will appear at S′, or 20° 21 in Gemini, corresponding with the 11th of June. The line which joins these points, will be a prolongation of the com-

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What causes the sun to have a small motion round the centre of gravity of the system?

62. What is deduced from the apparent paths of the solar spots? How much is the sun's axis inclined to the axis of the ecliptic? When does the apparent path of a spot appear as a straight line? What is the apparent path at all other times? What is the sun's longitude when the eccentricity of the path of a spot is the least?

mon intersection made by the planes of the solar equator and ecliptic, and consequently the eye of the observer will be in both planes; hence a spot on the sun's equator, in describing that circle, will appear to move along the straight line *e q*. But when the earth is at E′, the plane of the solar equator will present an oblique appearance to the observer's eye, and hence the spot will then appear to describe the curve *e r q*.

63. Sun's Motion in absolute Space. Astronomers have determined that certain stars slowly change their position in the heavens. While the apparent distances of some from each other are increasing, the distances of those in an opposite direction are diminishing. Hence it is inferred that the sun, and necessarily all the bodies connected with him, have a motion in absolute space, and are advancing towards one quarter of the heavens, and receding from the opposite point. This change in the position of the stars, is called their *proper motion.*

Sir William Herschel has come to the conclusion, from his observations on several stars, that the solar system (35) has a motion towards the constellation Hercules, and that this motion is not rectilineal, but performed round some immense body, the centre of all the systems with which astronomers have filled the regions of space. M. La Lande supposes that all the systems of the universe maintain an equilibrium, and have a periodical circulation round their common centre of gravity.

64. Zodiacal Light. A faint light resembling the milky way, but less bright, is seen at certain seasons of the year, after the end of twilight in the evening, and before it begins in the morning. This is called the Zodiacal Light. It is of a conical form, having its base turned towards the sun, and its axis inclined to the horizon in the direction of the zodiac. It varies in extent from 20° to 100°.

What is a consequence of the preceding result? Explain the foregoing principles by the diagram.

63. What is said of certain stars? What is inferred from this apparent change of position of some stars? What is Sir William Herschel's conclusion in relation to this matter? What does M. La Lande suppose?

64. Describe the zodiacal light. Of what form is it, and in what direction is the axis?

The best time for seeing the zodiacal light, is about the beginning of March, in the evening, and the beginning of October, in the morning. No satisfactory explanation has been given of this phenomenon, which, on account of its accompanying the sun, we have thought proper to notice in this place.

65. Astronomical Sign. The sun has for his astronomical sign, ☉, the circumference of a circle, with a point in the centre, which represent him as the centre of motion of the planetary system.

CHAPTER VI.

MERCURY.— ☿

66. Remarks. Mercury, the nearest of all the planets to the sun, emits a brilliant white light with a small tint of blue, and twinkles like the fixed stars. He may be seen, when the atmosphere is favorable, a little after sunset, and again a little before sun-rise. The observations of astronomers on this planet, on account of his proximity to the sun, and consequently his appearing but for a short interval above the horizon when the sun is below it, and that principally during the twilight, have been attended with difficulty, and considered somewhat uncertain.

Mercury appears to us, when viewed at different times through a telescope of sufficient magnifying power, with all the phases of the moon, except that he never appears quite full, because his enlightened side is never directly

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Has any satisfactory explanation been given of the zodiacal light?

65. What has the sun for his astronomical sign, and what does it represent?

66. Which is the nearest of all the planets to the sun? What is the appearance of Mercury? When may he be seen? On what account have the observations of astronomers on this planet been attended with difficulty? How does Mercury appear to us when viewed through a telescope?

opposite to us but when he is so near the sun as to be lost to our sight in the beams of that luminary. His enlightened side being always towards the sun, and his never appearing full, evidently prove that he shines not by any light of his own, but by the reflected light of the sun; and moreover, his never appearing above the horizon at midnight, shows that his orbit is contained within that of the earth, otherwise he would be seen in opposition (23) to the sun.

67. PERIOD AND DISTANCE. Mercury performs his periodical revolution round the sun in 87d. 23h. 15m. 43s. = 7600543s. of our time, which is the length of his year. The earth's siderial revolution round the sun is 365d. 6h. 9m. 11s. = 31558151s. Then by Kepler's third law (40) we have $31558151^2 : 7600543^2 :: 1^3 : \left\{\frac{7600543}{31558151}\right\}^2 =$ .058005091138; and $\sqrt[3]{.058005091138} = .387099$ nearly, the distance of Mercury from the sun, supposing the earth's distance to be 1. Hence, because the earth's distance is 24047 r (57), $.387099 \times 24047 = 9308.57$, the distance in semi-diameters of the earth; and $9308.57 \times 3956 = 36,824,703$ miles, the mean distance of Mercury from the sun.

The distance from the foot of a perpendicular, conceived to be let fall from the centre of a planet on the plane of the ecliptic to the centre of the sun, is called the *curtate distance* of the planet.

Also, 87d. 23h. = 2111h., and $36,824,703 \times 2 \times 3.1416 \div 2111 = 109,605$ miles, the mean rate at which this planet moves in his orbit per hour.

68. APPARENT DIAMETER AND MAGNITUDE. The ap-

What are the proofs that Mercury shines by the reflected light of the sun? What is the proof that his orbit is contained within that of the earth?

67. In what time does Mercury perform his periodic revolution? Knowing the earth's distance, how is Mercury's obtained? What is the mean distance in miles? What is the curtate distance of a planet? At what rate per hour does he move in his orbit, and how obtained?

parent diameter of Mercury varies between 5″ and 12″. When in his inferior conjunction (23), and at his mean distance, it is 10″.75. The mean distance of the earth from the sun is 24047*r*, and the mean distance of Mercury from him is 9308.57*r* (67). Hence 24047*r* — 9308.57*r* = 14738.43*r*, the mean distance of Mercury from the earth at his inferior conjunction; and as the apparent diameters of bodies are inversely proportional to their distances, we have 24047 : 14738.43 : : 10″.75 : 6″.58, the apparent diameter of Mercury at a distance from the earth equal to that of the sun. And because the sun's apparent diameter is 32′ 1″.8, and his real diameter 886,144 miles (58), therefore 32′ 1″.8 : 6″.58 : : 886,144*m*. : 3,034 miles, the real diameter of Mercury. Then since the magnitudes of spherical bodies are as the cubes of their diameters, it follows that $\left(\frac{7912}{3034}\right)^3 = (2.6)^3$ = 17.576, which shows how many times the magnitude of the earth exceeds that of Mercury.

69. Inclination of the Orbit and Transit. The orbit of Mercury is inclined 7° to the plane of the ecliptic, and that node (22) from which he ascends northward above the ecliptic, is in the sixteenth degree of Taurus; and consequently the descending node is in the sixteenth degree of Scorpio. The sun is in these points on the 6th of May and 8th of November; and when Mercury comes to either of his nodes at his inferior conjunction about these times, he will pass over the disc of the sun like a dark round spot, which phenomenon is called the transit of Mercury; but in all other parts of his orbit, he will go

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68. Between what quantities does the apparent diameter of Mercury vary? What is it when he is in his inferior conjunction, and at his mean distance? Knowing this and the mean distances of the earth and Mercury, how is the real diameter found? How many times does the magnitude of the earth exceed that of Mercury, and how determined?

69. How many degrees is the orbit of Mercury inclined to the plane of the ecliptic? In what signs and degree are the nodes? What will occur when Mercury comes to either node at his inferior conjunction?

either above or below the sun, and consequently his conjunctions will then be invisible.

It is found that the longitude of Mercury's node varies but little more than 1° in a century; hence his transits can only occur, for centuries to come, in the months of May and November, because the sun's longitude can agree with that of the nodes only in these months.

70. ROTATION ON THE AXIS, SEASONS, ETC. Mercury, according to Mr. Schroeter, of Lilienthal, performs a revolution on his axis in 24h. 5½m. The axis is said to make a large angle with a perpendicular to the plane of the ecliptic.

From the apparent diameters of Mercury taken at the time of his transits, and when at his aphelion and perihelion distances (38) the eccentricity of his orbit is obtained, which is about $\frac{1}{5}$ of his mean distance. On account of this great eccentricity of the orbit, Mercury's year is divided into seasons of very unequal length. The light which this planet receives from the sun, when in the perihelion, is 10 times as great as that which the earth receives, while it is but 5 times as great when in the aphelion. This is also a consequence of the great eccentricity of the planet's orbit. The intensity of heat at Mercury, if it were governed by the same law as that of light, would vary of course from 5 to 10 times its intensity at the earth. But we have no reason to conclude that *sensible* heat at the planets, is in the inverse proportion to the squares of their distances from the sun.

71. ASTRONOMICAL SIGN. Mercury was considered the messenger of the gods. His astronomical sign ☿ is supposed to represent the *caduceus* with which Apollo

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Why will his transits occur in the months of May and November for centuries to come?

70. In what time does Mercury revolve on his axis? What part of the mean distance is the eccentricity of the orbit, and how obtained? What is said of the seasons? What of the light which he receives? What of the intensity of the sun's heat at Mercury? What is the concluding remark on this subject?

71. Describe the astronomical sign of Mercury?

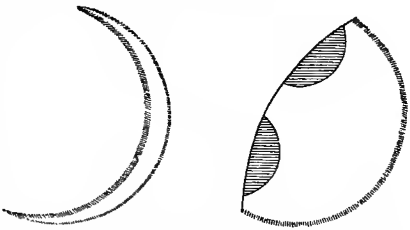
furnished him. It is a rod entwined at one end by two serpents in the form of two equal semi-circles, and winged at the top. The snakes are supposed to represent prudence, and the wings diligence.

CHAPTER VII.

VENUS.— ♀

72. REMARKS. Venus, the next planet in order, is to appearance the largest of all the planets, and is distinguished from them, by the brilliancy and whiteness of her light. Her orbit, including that of Mercury, is within the earth's orbit, for if it were not, she might be seen as often in opposition to the sun, as she is in conjunction with him; but she was never seen in our latitude, above the horizon at midnight, or 90° from the sun.

Venus, when viewed through a telescope, has all the phases of the moon, though she never or seldom appears perfectly round. (See the figures.)



73. PERIOD AND DISTANCE. Venus performs her revolution round the sun in 224d. 16h. 49m. 10s. = 19,411,750s. Hence, (67) $\left(\frac{19411750}{31558151}\right)^2 = .378454465832117$;

and $\sqrt[3]{.378454465832117} = .723332$, the distance of Venus from the sun, supposing the earth's distance = 1. Then $.723332 \times 24047r = 17394r$, the distance in semi-

72. How is Venus distinguished from the other planets? Is her orbit within that of the earth, and if so, how known? What is her appearance when viewed through a telescope?

73. In what time does Venus perform her revolution round the sun? From the periodic time, determine the mean distance.

diameters of the earth; and 17394 × 3956*m*. = 68,810,-664 miles, the mean distance of Venus from the sun. And since the intensity of light is reciprocally proportional to the squares of the distances from the source whence it emanates, we have

$$\left[\frac{1}{.723332}\right]^2 = 1.9.$$

This shows that the intensity of the light of the sun at Venus, is nearly double its intensity at the earth.

Venus performs her revolution round the sun in 224d. 17h. nearly = 5393*h*. Hence,

$$\frac{68{,}810{,}664 \times 2 \times 3.1416}{5393} = 80168 \text{ miles.}$$

This distance is equal to the velocity per hour of Venus in her orbit.

74. Apparent Diameter and Magnitude. The greatest and least apparent diameters of Venus are 61″ and 10″. When she is in her inferior conjunction and at her mean distance, the apparent diameter is about 60″. Then 1—.723332 = .276668 (73) the distance of Venus from the earth at her inferior conjunction, the earth's distance from the sun being equal to unity; and 1 : .276668 : : 60″ : 16″.6, the apparent diameter of Venus at a distance from the earth equal to that of the sun. Again, 32′ 1″.8 : 16″.6 : : 886144*m*. : 7654 miles, the real diameter of Venus. Hence, we have $\left(\frac{7654}{7912}\right)^3 = .905$, making her volume about $\frac{9}{10}$ that of the earth.

From the small variations in the apparent diameters of Venus at or near her inferior conjunctions, the eccentricity of her

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What is the mean distance in miles? Determine the comparative intensities of the sun's light at Venus and the earth. What is the velocity, per hour, of this planet in the orbit?

74. What is the apparent diameter of Venus, when in her inferior conjunction, and at her mean distance? From this determine the real diameter. What is her volume compared with that of the earth? From what circumstance is her orbit found to be very nearly circular?

orbit is determined to be about .00688, or less than half a million of miles; hence, it is very nearly circular.

75. Rotation on the Axis and Seasons. Mr. Schroeter found the period of the daily rotation of Venus on her axis to be 23*h*. 21*m*. This he deduced from the different shapes which the horns assumed. He observed that the appearance of her horns varied, and after an interval of time, again assumed the same appearance. Hence, by noticing this interval, he concluded that the time of the rotation is as already stated, 23*h*. 21*m*., and that her axis makes a considerable angle with the perpendicular to the plane of the orbit. Some authors state that this angle amounts to 72°; and consequently the length of her days and nights, and the vicissitudes of her seasons, are subject to great and rapid changes.

76. Morning and Evening Star. When Venus appears west of the sun, or when her longitude is less than the sun's longitude, she will rise in the morning before him, and is then called a *morning star;* but when she appears east of the sun, or when her longitude is greater than the sun's longitude, she shines in the evening after sunset, and is then called an *evening star*.

This planet, when a morning star, was called by the ancient poets, *Phosphorus* or *Lucifer*, and when an evening star, *Hesperus* or *Vesper*, having been regarded by them as two different bodies. Venus is a morning star for 292 days, and an evening star for the same length of time.

Suppose Venus in her inferior conjunction. Put $P =$ the periodic revolution of the earth in days, $P' =$ the periodic revolution of Venus, and $1 =$ the circumference of the circle. Then we have,

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75. What is the time of the rotation of Venus on her axis, and how deduced? What is the inclination of her axis? What is the consequence of this great inclination of the axis?

76. When is Venus a morning star, and when an evening star? What called by the ancient poets? How long does she continue alternately a morning and an evening star?

$\frac{1}{P}$ = the daily progress of the earth in its orbit,

$\frac{1}{P'}$ = " " Venus in her orbit,

and $\frac{1}{P'} - \frac{1}{P} = \frac{P-P'}{P\,P'}$ = the daily gain of Venus on the earth;

hence, $\frac{P-P'}{P\,P'} : 1 :: 1d. : \frac{P\,P'}{P-P}d$ = the time which elapses until Venus comes again to her inferior conjunction.

If we substitute for P $365\frac{1}{4}$ and for P′ $224\frac{2}{3}$, the fourth term of the above proportion will give 584 days nearly, the synodic revolution of Venus; and 584 days ÷ 2 = 292 days, the time which she continues alternately a morning and an evening star. By substituting in the same formula for P′ 88, we will find the synodic revolution of Mercury about 116 days.

77. Inclination of the Orbit and Transit. The orbit of Venus makes an angle of 3° 23′ 28″ with the plane of the ecliptic, and the ascending node is 15° in Gemini, hence the descending node is 15° in Sagittarius; therefore when the sun is in or near these points of the ecliptic, and Venus in her inferior conjunction, she will pass over his disc like a dark spot, called the transit of the planet. The sun's longitude agrees with the longitude of the nodes on the 5th of June and 7th of December.

Let E E′ E″ represent the orbit of the earth coinciding with the plane of the paper, *v v′ v″* that part of the orbit of Venus above the plane of the earth's orbit, and *v″ v‴ v*, that part below it.

When the earth is in Gemini at E, or the sun in Sagittarius, and Venus at *v* in her inferior conjunction, and in or near her ascending node, being then in a direct line between the earth and the sun, she will evidently appear like a dark spot on the sun. The same phenomena will

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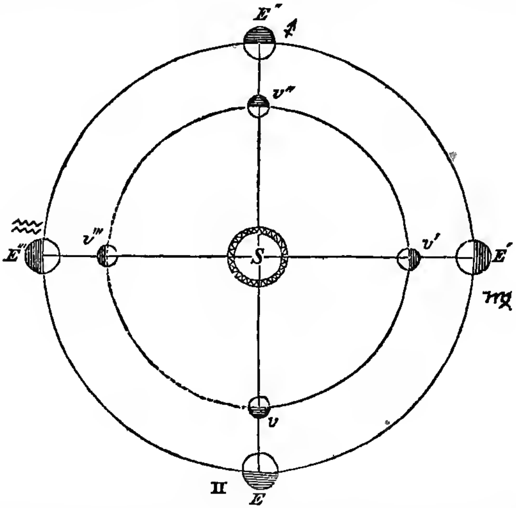
From the periodic times of the earth and Venus, deduce the synodic revolution of Venus. How is the synodic revolution of Mercury found?

77. How many degrees is the orbit of Venus inclined to the plane of the ecliptic? What are the longitudes of the nodes?

occur when the earth is in Sagittarius at E″, or the sun in Gemini, and Venus in or near her descending node at v″. But when the earth is at E′ and Venus at v′, or when the earth is at E‴ and Venus at v‴, although in



both cases she is at her inferior conjunction, there will be no transit; because in the one case she will pass above the sun, and in the other below him. In a similar manner, a transit of Mercury may be illustrated.

78. Frequency of the Transits of Mercury and Venus. It has already been observed that a transit of one of the interior planets (36) cannot occur, unless the planet is in or near one of the nodes, and at the time of the inferior conjunction; therefore, when a transit has

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What will occur when the sun is in or near these points, at the time Venus is in her inferior conjunction? Draw the diagram, and illustrate a transit of Venus or Mercury.

78. When a transit has occurred at one node, of what must the period of time that elapses be composed, before another transit can happen at the same node?

occurred, another will not happen at the same node, till the lapse of a period of time composed of a whole number of periodic revolutions of the planet and the earth, or nearly so. And again, another transit will not occur at the opposite node, till the lapse of a period of time composed of an odd whole number of half periodic revolutions of the planet and the earth, or nearly so.

Hence let P represent the periodic revolution of the earth, P′ that of an interior planet Mercury or Venus, and m and n two whole numbers, such that $m\,P = n\,P'$ nearly; then will m be the number of years between two consecutive transits at the same node. Or, let m and n represent two odd whole numbers, such that $m\,\frac{P}{2} = n\,\frac{P'}{2}$ nearly, then will m be the number of half years between any two consecutive transits at opposite nodes. Let us examine the first equation:

$m\,P = n\,P'$, or $n = \frac{m\,P}{P'}$, which gives in the case of Mercury,

$$n = \frac{365\tfrac{1}{4}m}{88} = \text{a whole number},$$

or $\frac{365\tfrac{1}{4}m}{88} - \frac{352\,m}{88} = \frac{13\tfrac{1}{2}\,m}{88}$ = a whole number nearly.

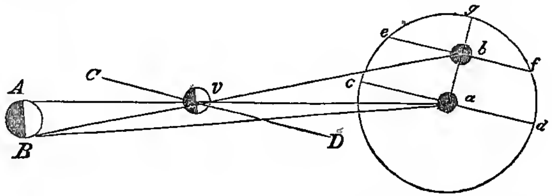
This gives for m 13, 7; and the whole number of half years in the second equation will be 19, 7. Hence the transits of Mercury will occur at intervals of 13, 7, 9½, 3½, 9½, and 3½ years, taken in order, and repeated again in the same order. The last transit of Mercury occurred May 8th, 1845; the next will occur November 9th, 1848. A full investigation of the same equations with reference to Venus, using 224⅔ in place of 88, will show that her transits will occur at intervals of 105½, 8, 121½, and 8 years, taken in order, and repeated again in the same order. The last transit of Venus occurred June 3d, 1769; the next will occur at the opposite node, after the lapse of 105½ years, or December 8th, 1874.

Of what must it be composed before a transit occurs at the opposite node? Illustrate these principles. At what intervals will the transits of Mercury occur? Those of Venus? When did the last transit of Mercury occur, and when will the next happen? When did the last of Venus occur, and when will the next?

These investigations of the transits of Mercury and Venus agree in their results with those calculated from the tables of La Lande.

79. The Sun's Parallax determined by means of a Transit of Venus. A transit of Venus is a phenomenon of great importance, as furnishing the best means by which the sun's parallax may be determined. The following illustration will enable the student to understand the general principles on which the solution of this great problem depends.

Let A and B represent the places of two observers, situated at opposite extremities of that diameter of the earth which is perpendicular to the plane of the ecliptic, *v* Venus passing through C D, part of her relative orbit, and in the direction from C to D, and *c d g* the sun's disc, the plane of which for each observer may be regarded as perpendicular to the plane of the ecliptic.



To an observer at A, the centre of the planet will appear to describe on the sun's disc, the chord *c d*, and to an observer at B, the parallel chord *e f*. Now, by knowing the exact times of the duration of the transit as observed at both these places, and also knowing the relative hourly motion of Venus in her orbit, the values of the chords *c d* and *e f*, expressed in seconds of a degree, also become known; and hence knowing the sun's apparent diameter, the value of *a b*, the distance between the chords, or the difference between their versed sines, is easily found. Again, because the relative orbit of the planet, and consequently the chords *c d* and *e f*, make but a small angle with the plane of the ecliptic, *a b* may be regarded as parallel

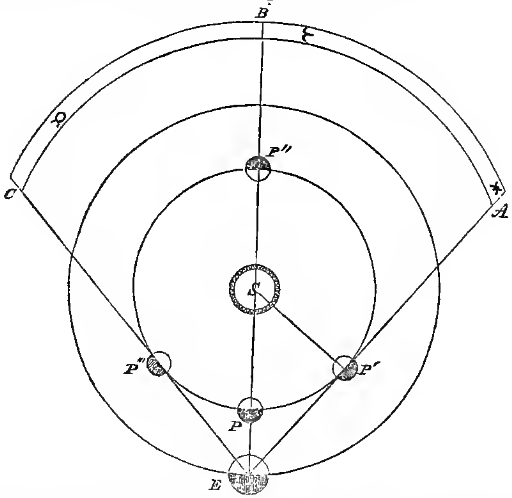
79. Why is a transit of Venus a phenomenon of great importance? Draw the diagram, and illustrate the general principles on which the solution of this great problem depends.

to A B; therefore the triangles A B v and $a\ b\ v$ are similar, and give the proportion, $a\ v$: A v : : $a\ b$: A B; but $a\ v$: a A : : .723 - - - : 1 (73), and $a\ v$: a A — $a\ v$ = A · : : .723 - - - : 1 — .723 - - - = .276 - - -; hence .723 - - - : .276 - - - : : $a\ b$: A B = $\frac{276}{723}\ a\ b$ = $\frac{2}{5}\ a\ b$ nearly. And since A B measures the angle A a B, it follows that the sun's horizontal parallax, or $\frac{1}{2}$ A a B = $\frac{1}{5}\ a\ b$ nearly.

We see from this method, that whatever error may be committed in determining $a\ b$, the error in the parallax will be but one-fifth as great. In an exact calculation, the rotation of the earth on its axis, or whatever would affect an accurate result, must be taken into consideration.

On account of the nearness of Mercury to the sun, and consequent small difference in their parallaxes, his transits are not suitable for determining the solar parallax.

80. Retrograde and Direct Motions of the interior Planets. Let S represent the sun, P an interior planet, as Mercury or Venus, E the earth, A B C a portion of the heavens, and P P′ P″ the planet's orbit.



In an exact calculation, what must be taken into consideration? Why are the transits of Mercury not suitable for determining the solar parallax?

When the planet P is at its inferior conjunction, it will be invisible, because its dark side is turned towards E the earth, unless it be in one of its nodes, in which case it will be seen on the sun's disc like a dark spot. As the planet advances in its orbit from P to P′, its enlightened side will become gradually visible, and it will appear west of the sun, being then a morning star. When it has arrived at P′, or at its greatest western elongation (23), half its enlightened side will be seen from E, the earth, like a half moon. Now, during this motion of the planet from P to P′, it will appear to an observer at E, to move from B to A in the heavens, or to go backwards, which is called its *retrograde motion;* and during its motion from P′ to P″, it will appear to move from A to B in the heavens or forward, called its *direct motion;* and when at P″, it will appear in the same place in the heavens as when at P, being then in its superior conjunction.

In going from P″ to P‴, it will become east of the sun and an evening star, and will appear to move from B to C in the heavens; and when moving from P‴, its greatest eastern elongation, to P, it will appear to go backwards again in the heavens from C to B; and when at P, it will again disappear, and pass by the sun.

81. Distances of Mercury and Venus, determined from their elongations.

Join S P′, (see last fig.) and in the right-angled triangle E P′ S, right-angled at P′, we have the angle S E P′ = the planet's greatest elongation, and E S = the distance of the sun from the earth, to find P′ S the planet's distance from the sun. Mercury's greatest elongation is 28° 20′, when he is in his aphelion and the earth in its perihelion; but when Mercury is in his perihelion and the earth in its aphelion, the greatest elongation is 17° 36′; the mean is therefore 22° 58′. Then—

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80. Draw the diagram, and illustrate the retrograde and direct motions of the interior planets.

81. What is the greatest elongation of Mercury, when he is in his aphelion and the earth in its perihelion? And what is it when the planet is in the perihelion and the earth in the aphelion? From the mean of the greatest elongations, determine the planet's distance. According to

as Radius 90° *ar. co.*	0.0000000
is to *sin* S E P′ 22° 58′ . .	9.5912823
so is E S 24047*r*.	4.3810609
to P′ S 9383*r*.	3.9723432

Hence 9383 × 3956*m*. = 37,119,148 miles, the distance of Mercury from the sun, according to this method.

According to La Lande, the greatest elongations of Venus are 47° 48′ and 44° 57′; when she and the earth are in situations similar to those of Mercury and the earth noticed near the beginning of this article, the mean is 46° 22′ 30″. Hence—

as Radius 90° *ar. co.*	0.0000000
is to *sin* S E P 46° 22′ 30″ . .	9.8596611
so is E S 24047*r*.	4.3810609
to P′ S 17406.92*r*.	4.2407220

Hence 17406.92 × 3956*m*. = 68,861,775 miles, the distance of Venus from the sun, agreeing very nearly with her distance already found by another method (73).

Since these distances so nearly agree with those found by Kepler's third law, and since the times of the stationary appearances and retrogradations obtained by calculation based on the order and motions of Mercury, Venus, and the earth, in the Copernican System, also agree with the times of observation of these phenomena, we have a strong proof of the truth of that system.

82. Astronomical Sign. The astronomical sign of Venus, ♀, is said to represent a mirror furnished with a handle at the bottom.

La Lande, what are the greatest elongations of Venus? From the mean of these elongations, determine the distance of Venus. Do these distances of Mercury and Venus nearly agree with those found by Kepler's third law? What strong proof have we of the truth of the Copernican system?

82. Describe the astronomical sign of Venus.

CHAPTER VIII.

THE EARTH—⊕

83. Remarks. The earth, or the globe which we inhabit, is the next planet above Venus. Its surface is composed of land and water, about one-fourth being land and the remainder water. The water assumes a regular or uniform surface, but the land is irregular in its surface, occasioned by mountains and valleys. The earth is surrounded by an atmosphere varying in density, supposed to extend to the height of about fifty miles. By experiments in the science of Pneumatics, we learn that the atmosphere is an elastic medium, the density of which, being greatest at the earth's surface, decreases as the distance increases. At the height of 3½ miles, the density is but one-half that at the surface. The density of the atmosphere is so small at the height of 49 miles (52), that it ceases to reflect the sun's rays.

84. Period and Distance. The earth performs its siderial or periodic revolution round the sun, describing an elliptic orbit (22), in 365*d.* 6*h.* 9*m.* 12*s.*, but its tropical revolution in 365*d.* 5*h.* 48*m.* 48*s.* from any equinox or solstice (14), to the same again, which is the length of our year. Its distance from the sun, already determined (57), is 95,129,932 miles, and 365*d.* 6*h.* = 8766*h.*; therefore—

$$\frac{95{,}129{,}932 \times 2 \times 3.1416}{8766} = 68{,}186 \text{ miles, the mean rate}$$

of the earth's motion per hour in its orbit.

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83. Which is the next planet to Venus? Give a description of the earth's surface. To what height is the atmosphere supposed to extend? Where is the density of the atmosphere the greatest? What is it at the height of 3½ miles? At what height does it cease to reflect the sun's rays?

84. In what time does the earth perform its siderial or periodic revolution round the sun? In what time its tropical revolution? What is the length of our year? At what rate does the earth move in its orbit per hour?

85. Eccentricity of the Orbit.

When the earth is in the perihelion, the sun's apparent diameter will be the greatest; and when in the aphelion, it will be the least. The greatest and least apparent diameters are respectively found to be 32′ 34″.6 and 31′ 30″.1; hence the earth's relative distances when in these points, and consequently the eccentricity of its orbit, may be determined. Thus let e = the eccentricity, D = the greatest apparent diameter, d = the least, A = the aphelion or greatest distance, and P = the perihelion or least distance, and we shall have $D : d :: A : P$; whence $D + d : D - d :: A + P : A - P$, or $D + d : D - d :: \frac{A + P}{2} : \frac{A - P}{2}$; but $\frac{A + P}{2}$ = the semi-axis major = 1; and $\frac{A - P}{2} = e$; wherefore $D + d : D - d :: 1 : e$, and consequently $e = \frac{D - d}{D + d} = .0168$ by substitution, the eccentricity of the earth's orbit.

Since the sun's apparent diameter is greatest about the beginning of January, and least about the beginning of July, it follows that $95{,}129{,}932m. \times .0168 \times 2 = 3{,}196{,}365$ miles, which shows how much nearer the earth is to the sun in winter than summer.

86. Figure of the Earth. That the earth is spherical, or nearly so, is not only evident from its shadow upon the moon in lunar eclipses, which shadow is always bounded by a circular line, but also from the many circumnavigators who have sailed round it at different times, and the observations of persons at sea or on the shore, in viewing a vessel depart from them; they first lose sight of the hull, while they can see the rigging and topsails; but as she recedes farther from them, they gradually lose sight of these also, the whole being hid by the convexity of the water.

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85. What are the greatest and least apparent diameters of the sun? From these determine the eccentricity of the earth's orbit. How much nearer is the earth to the sun in winter than summer?

86. What is the figure of the earth? From what facts is it evident that the earth is spherical, or nearly so?

87. THE EARTH IS AN OBLATE SPHEROID. Though the earth may be considered as spherical, yet it has been discovered that it is not truly so. This matter was the occasion of great disputes between the philosophers of the last age, among whom Sir Isaac Newton and James Cassini, a French astronomer, took the most active part in the controversy. Sir Isaac demonstrated from mechanical principles that the earth was an *oblate spheroid*, or that it was flatted at the poles, the polar diameter or axis being shorter than the equatorial diameter. The French astronomer asserted the contrary, or that it was a *prolate spheroid*, the polar diameter being longer than the equatorial diameter.

The French king, in 1736, being desirous to end the dispute, sent out two companies of the ablest mathematicians then in France, the one towards the equator, and the other towards the north pole, in order to measure a degree of a meridian in these different parts. From the results of their admeasurements, the assertions of Cassini were rejected, and those of Newton confirmed beyond dispute. Therefore, since that time the form of the earth has been considered as that of an oblate spheroid, that is, of a solid such as would be generated by the revolution of a semi ellipse about its minor axis.

88. DIAMETER OF THE EARTH. From the most accurate measurements it has been found that the equatorial diameter of the earth is 7925 miles, and the polar diameter or axis, 7899 miles, the difference, being 26 miles, is about $\frac{1}{305}$ of the equatorial diameter, called the *ellipticity* or

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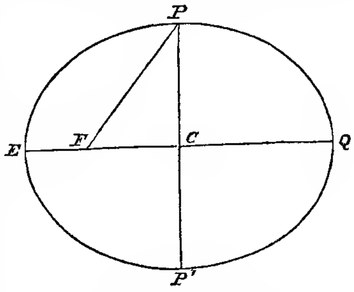
87. Is the earth truly spherical? What did Sir Isaac Newton demonstrate concerning it? What were the assertions of Cassini on this subject? What was done, and when, in order to ascertain its true form? What followed the results of these admeasurements? What has the form of the earth been considered since that time?

88. How long are the equatorial and polar diameters of the earth respectively? What part of the equatorial diameter is the difference, and what called? What is said of this difference, and the unevenness of the earth's surface?

oblateness of the earth. But this difference is so small, and the unevenness of the surface, arising from mountains, hills, &c., so inconsiderable, when compared with the magnitude, that in all practical sciences we may consider the earth as a sphere; and hence, the artificial globes, being made perfectly spherical, are the best representations of the earth. The mean diameter is therefore 7912 miles, the radius 3956 miles, and the length of a degree of a great circle, 69 miles.

89. A Terrestrial Meridian is an Ellipse. Let E P Q P′ represent an ellipse. It is evident that the curvature of the arc E P diminishes from the extremity of the axis major to that of the axis minor, or from E to P, and as the curvature of the arc decreases, the radius of that arc increases; hence, the length of a degree on the arc E P, will increase from E to P. Now, from the most accurate measurements this is found to be the case of a terrestrial meridian from the equator to the pole; and from the different lengths of a degree in different latitudes, it is proved that a meridian is an ellipse, or nearly so. If the semi-ellipse P E P′ were to revolve about P P′, its minor axis, it would generate a solid called an oblate spheroid, such is the form of the earth. When the revolution is made about E Q, the axis major, the solid is called a prolate spheroid.



90. Eccentricity of the Earth. The eccentricity of the

How long is the mean diameter? The radius? A degree of a great circle?

89. Draw the diagram, and show how it is determined that a terrestrial meridian is an ellipse.

90. Define what is understood by the eccentricity of the earth.

earth is the difference between its centre and one of the foci of an elliptical meridian. Thus let C (see last fig.) be the centre, and F one of the foci of the ellipse E P Q P′, then will F C = the eccentricity. If the equatorial radius E C = 1, we will have by the property of the ellipse F P = E C = 1, and by the oblateness of the earth (88), $CP = 1 - \frac{1}{305} = \frac{304}{305}$; but $FC = \sqrt{FP^2 - CP^2} = \sqrt{1 - (\frac{304}{305})^2} = \sqrt{\frac{609}{305}} = .08091$ = the eccentricity, the radius of the equator being unity.

91. Rotation on the Axis. The earth revolves once on its axis from west to east in 23h. 56m. 4s. which is the time that elapses from the passage of any fixed star over the meridian till it returns to the same meridian again. This motion of the earth, which is the most equable in nature, causes all the heavenly bodies to have an apparent diurnal motion in the same time, from east to west, making the vicissitudes of day and night. Besides the motion of the earth in its orbit (84), which is common to every place on its surface, the inhabitants of the equator are carried from west to east 1037 miles per hour by the daily rotation of the earth on its axis. Thus

$$\frac{7925 \times 3.1416}{24} = 1037 \text{ miles.}$$

92. Inclination of the Axis and Seasons. The earth's axis makes an angle of 23° 28′ with the axis of the orbit, and preserves the same oblique direction during its annual course, or keeps always parallel to itself; hence, during one part of the earth's course, the north

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Assuming the radius of the equator equal to unity, and knowing the oblateness, determine the eccentricity.

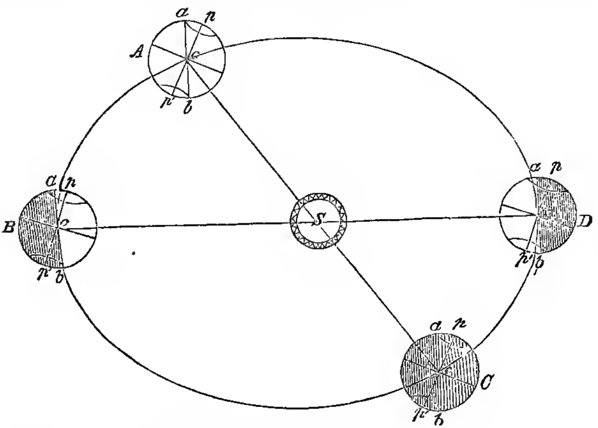
91. In what time does the earth revolve on its axis? Which is the most equable motion in nature? What causes all the heavenly bodies to have an apparent diurnal motion from east to west? On what do the vicissitudes of day and night depend? How far are the inhabitants of the equator carried per hour by the rotation of the earth on its axis?

92. What angle does the earth's axis make with the axis of the orbit? What does the axis preserve during the earth's annual course? What is the consequence of the axis preserving its parallelism?

pole is turned towards the sun; and during the other part of its course, the south pole is turned towards him in like manner. This change in the position of the poles with regard to the sun, causes the variations in the lengths of days and nights, and the different seasons of the year.

Let S represent the sun, A B C D the earth's orbit, made sensibly elliptical, and $p\ p'$ the earth's axis making an angle of 23° 28′, with the line $a\ b$ passing through its centre, and perpendicular to the plane of the orbit or ecliptic. The sun illuminates half of the earth's surface at the same time, hence, the boundary of light and darkness, called the *circle of illumination*, is a great circle (6). It is evident that the plane of this circle will be perpendicular to a line drawn from the centre of the sun to the centre of the earth, called the radius vector.

When the earth is in Libra at A, the sun will appear in Aries, his polar distance being 90° (16), and the angle $p\,c\,S$, which measures this distance, must be a right angle, hence the circle of illumination will pass through the poles p and p', and consequently will not only bisect the equator, but all the parallels



What does this change in the position of the poles with regard to the sun cause? Draw the diagram, and fully illustrate the cause of the variations in the lengths of the day and night, and the different seasons of the year.

of latitude (7, 14); and as all places on the surface of the earth during one rotation will be as long on one side of the circle of illumination as on the other, it follows that when the sun enters Aries, or at the time of the vernal equinox (13), he shines from pole to pole, and all the inhabitants of the earth have equal day and night. In this position of the earth, the circle of illumination will appear to the eye, placed in the plane of the ecliptic at a distance below the figure, as the circle $p\ a\ p'\ b$.

While the earth advances from Libra to Capricorn, the angle $p\ c\ S$ decreases, causing the north pole p to turn towards the sun, and the south pole p' from him, hence the circle of illumination will cut the parallels of latitude unequally, and therefore the length of the days in the northern hemisphere will continue to increase, and the length of those in the southern hemisphere proportionally to decrease. When the earth enters Capricorn at B, the sun will appear to enter Cancer, at which time the angle $p\ c\ S$ will be the least, or 66° 32′, and consequently the inclination of the axis to the plane of the circle of illumination will be the greatest, or 23° 28′, equal to $p\ c\ a$, the obliquity of the ecliptic; hence, when the sun enters Cancer or at the time of the summer solstice (13), the inhabitants of north latitude have their longest day and shortest night, and those of south latitude, their longest night and shortest day. At this time the whole of the north frigid zone (28) will have constant day, and the whole of the south frigid zone constant night. In this position of the earth the circle of illumination appears as the straight line $a\ b$. As the earth advances from Capricorn to Aries, the angle $p\ c\ S$ increases, and consequently the length of the days in the northern hemisphere will decrease, and the length of those in the southern hemisphere will increase. When the earth enters Aries at C, the sun will appear to enter Libra, and then the angle $p\ c\ S$ will be 90°; hence, at the time of the autumnal equinox, all the inhabitants of the earth will again have equal day and night. In this position of the earth the dark hemisphere is turned towards the eye. Thus from the vernal to the autumnal equinox, it will be constant day at the north pole, and constant night at the south pole; and in other parts of the north and south frigid zones, the time of continued day in the one and continued night in the other, will vary from 24 hours to six months, being longer as the latitude of the place is greater

Again, as the earth advances through the other part of its orbit, or from Aries to Libra, the angle $p\,c\,S$ will be greater than 90°, hence during this period, or from the autumnal to the vernal equinox, the north pole will be turned from the sun, and the south pole towards him, causing the night to be longer than the day in the northern hemisphere, and the day longer than the night in the southern hemisphere. When the earth enters Cancer at D, the sun will appear to enter Capricorn, at which time the angle $p\,c\,S$ will be the greatest, or 113° 28′, and the inclination of the axis to the plane of the circle of illumination will again be equal to the obliquity of the ecliptic; hence, when the sun enters Capricorn, or at the time of the winter solstice, the lengths of the day and night are the reverse of their lengths when the sun enters Cancer, or at the time of the summer solstice. Lastly, when the earth enters Libra the sun will again appear to enter Aries, and the circle of illumination will pass through the poles; hence, from the autumnal to the vernal equinox it will be constant night at the north pole, and constant day at the south pole. At all places situated on the equator, the lengths of the days and nights throughout the year are equal, being 12 hours each, because the equator, being a great circle, is bisected (6) by the circle of illumination.

93. Astronomical Sign. Astronomers call the earth *Tellus*, the astronomical sign of which ⊕ represents the terrestrial globe with its equator and axis.

CHAPTER IX.

THE MOON.—☽

94. Remarks. The moon is the nearest celestial body to the earth, and the next to the sun, from appearance, in splendor. Her apparent motion, like all the heavenly

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93. Describe the astronomical sign of the earth.

94 Which is the nearest celestial body to the earth?

bodies, is from east to west, caused by the rotation of the earth on its axis in a contrary direction. By observing her motion among the fixed stars, we will perceive that it is from west to east, and that in a period of time a little less than a month, she will have completed her circuit in the heavens. This motion of the moon round the earth is real; besides which, she accompanies the latter in its annual revolution round the sun. The moon is a secondary planet, and the earth's satellite.

95. SIDERIAL REVOLUTION. It was observed in the last article, that the moon revolves round the earth from west to east, or from any one point in the heavens or fixed star to the same again, in less than a month. The exact time of this revolution is 27*d.* 7*h.* 43*m.* 5*s*, which period is called the moon's siderial revolution, or the periodic month. The siderial revolution is determined by observation.

96. SYNODICAL REVOLUTION. The synodic revolution, or the time that elapses between two consecutive conjunctions or oppositions of the sun and moon, may be deduced from the siderial revolution.

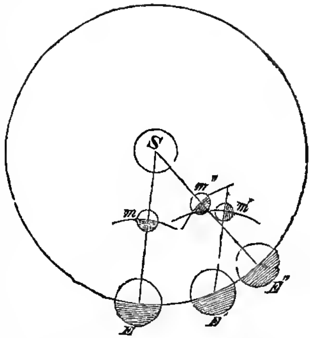
Let E represent the earth, and m the moon in conjunction with S the sun. After the lapse of a siderial revolution, the earth will have advanced in its orbit to E′, and the moon to m', or the same longitude as when at m; the line joining E and m being parallel to that joining E′ and m', because two lines, supposed to be drawn from any two points of the earth's orbit to a fixed star, are sensibly parallel, on account of the immense distance to that star.

What is the apparent motion of the moon, and by what caused? In what time, and in what direction, does she complete her circuit in the heavens? Is this motion round the earth, real? Besides this, what other motion has she? Is the moon a secondary planet? Of what planet is she the satellite?

95. What is the exact time of the moon's revolution round the earth, and what called? How is the siderial revolution determined?

96. Define the synodic revolution. From what may it be deduced?

Now it is evident, before another junction can take place, the earth will have moved to E″, and the moon to m'', as represented in the figure. When the sun and moon are in conjunction, their longitudes are equal; and before another conjunction can occur, the excess of the moon's motion in longitude over that of the sun's, must be **360°**, or one circle.



Thus put P = the periodic revolution of the earth in days, and P′ = that of the moon, also in days. Then—

$$\frac{1}{P} = \text{the mean daily motion of the sun in longitude,}$$

$$\frac{1}{P'} = \text{the mean daily motion of the moon in longitude,}$$

and $\frac{1}{P'} - \frac{1}{P} = \frac{P - P'}{P' P}$ = the daily gain of the moon's motion in longitude over that of the sun. Hence—

$$\frac{P - P'}{P' P} : 1 :: 1\ d. : \frac{P' P}{P - P'}\ d.$$

By substituting, in the fourth term of this proportion, the values of P and P′, we obtain 29*d.* 12*h.* 44*m.* nearly, for the synodic revolution, or the time that elapses from one change to another. This interval from new moon to new moon again, is called a *Lunar Month,* and sometimes a *Lunation.*

The value of $\frac{1}{P}$ or $\frac{360°}{P} = \frac{360°}{365.2564} = 59'\ 8''$ gives the sun's mean daily motion in longitude; and

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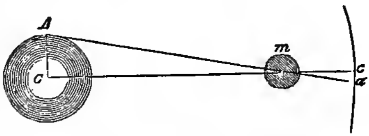
Draw the diagram, and explain the principles on which the synodic time depends. From the periodic or siderial times of the earth and moon, deduce the synodic revolution. What is this interval from new moon to new moon again, called? What is the amount of the sun's mean daily motion in longitude? What that of the moon's?

$$\frac{1}{P'} \text{ or } \frac{360^\circ}{P'} = \frac{360^\circ}{27.3216} = 13^\circ\ 10'\ 35''$$

gives the moon's mean daily motion in longitude. Hence, $13^\circ\ 10'\ 35'' - 59'\ 8'' = 12^\circ\ 11'\ 27''$ the moon's daily gain in longitude over the sun.

97. Distance. The moon's mean equatorial parallax has been found equal to 57′ 1″ (55).

Let A C represent the equatorial radius of the earth, or semidiameter at the equator, and *m* the moon; join A *m* and C *m*. Then from C the centre, the moon will appear at *c*, her true place; and from A, a place on the equator, she will appear at *a*, her apparent place.



In the right-angled triangle A C *m*, right-angled at C, we have the angle A *m* C = *a m c* = 57′ 1″ = the difference between the true and apparent place of the moon, viewed from the equator when in the horizon or the equatorial horizontal parallax, and A C = the equatorial radius of the earth $= r = 1$ to find A *m* = the moon's mean distance from the earth. Therefore—

as sine A *m* C, 57′ 1″ ar. co. . . .	1.7802920
is to Radius, 90°	10.0000000
so is A C 1, *r*, 1	0.0000000
to A *m*, 60.2934 *r*	1.7802920

Then 60.2934 × 3962.5*m*. (88) = 238,913 miles, the mean distance of the moon from the earth.

Or, according to the formula in Article 56 for finding the sun's distance, we have—

$$A\,m = \frac{\text{Radius}}{H}\,r = \frac{206264''}{3421''}\,r = 60.2934\,r.,$$

a result equal to that found above by trigonometrical calculation.

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97. What is the amount of the moon's mean equatorial parallax? Describe the parallax by means of the diagram. Knowing the parallax and the equatorial radius of the earth, find the moon's mean distance from the earth in miles. Give another method of finding her distance.

98. APPARENT DIAMETER AND MAGNITUDE. The apparent diameter of the moon at her mean distance is 31′ 7″, and her equatorial horizontal parallax 57′ 1″, or the angle which the earth's semi-diameter subtends, as seen from the moon; therefore 57′ 1″ × 2 = 1° 54′ 2″, the apparent diameter of the earth, as seen from the moon. Then 1° 54′ 2″ : 31′ 7″ : : 7925*m.* : 2162 miles, the moon's diameter. Hence—

$$\left\{\frac{7912}{2162}\right\}^2 = 13.4 \text{ nearly,}$$

which shows that the earth appears thirteen times as large to the moon, as the moon appears to us; and—

$$\left\{\frac{7912}{2162}\right\}^3 = 49,$$

making her magnitude or volume $\frac{1}{49}$ that of the earth.

99. PHASES OF THE MOON. Let E represent the earth S the sun, and *a b c*, &c. the moon in different parts of her orbit.

Since the moon is an opaque body like the earth, and consequently shines by reflecting the light received from the sun, she will disappear when at *a* in conjunction, having her dark hemisphere towards the earth, it being *new moon*, or at the change. After she has advanced in her orbit to *b*, a portion of her enlightened hemisphere on the right will be turned towards the earth; and as this is contained between the circle of vision and circle of illumination, it will evidently present the appearance of a crescent, the convex part being towards the sun, and the horns towards the east. Such will be the appearance of the moon when first seen after the change. When the moon has advanced to *c*, or 90° from the sun, the circle of illumination will present the appearance of a straight

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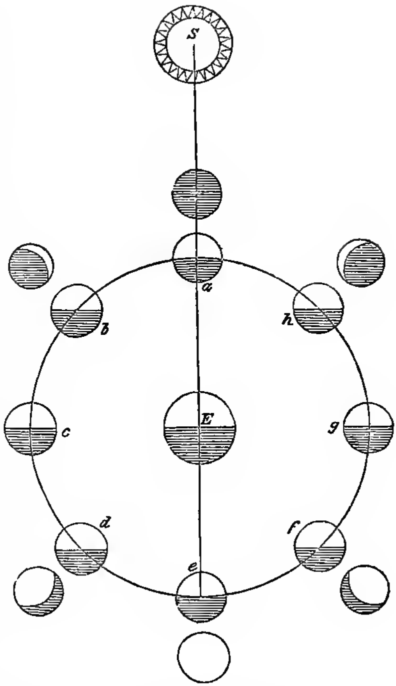
98. What is the apparent diameter of the moon at her mean distance? From the apparent diameter and equatorial horizontal parallax, find the real diameter. How much larger does the earth appear to the moon than the moon does to us, and how found? How does her volume compare with that of the earth, and how found?

line, and consequently she will appear as a semi-circle. She is now said to be in her *first quarter*. When at *d*, the circle of illumination will be on the left, and consequently more than the half of the enlightened hemisphere will be visible. The form of her enlightened disc is now said to be *gibbous*. At *e*, in opposition, the whole of the enlightened hemisphere will be turned towards the earth, and consequently she will appear like a complete luminous circle, which we then call *full moon*.



As the moon advances from opposition eastward in her orbit, a part of the dark hemisphere will be turned towards the earth, and she will become deficient on the western limb, which will now be bounded by the circle of illumination. When at *f g h*, she will present the same phases in order, but reversed, as at *d c b*. At *g*, or when 90° from the sun, she is said to be at her *last quarter*, and again her enlightened disc will appear as a semi-circle. The interval from new moon to the first quarter, and from the first quarter to the full, is each about 7½ days. A corresponding time,

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99. Draw the diagram, and show the different phases of the moon during one lunation.

elapses from full to the last quarter, and from the last quarter to new moon again.

When the moon is first seen after the change, the line connecting the horns will be differently inclined to a vertical circle at different seasons of the year. Thus about the time of the vernal equinox, the line connecting the horns will be most inclined to a vertical circle, because this portion of the ecliptic, in which the moon is nearly situated, makes with the western horizon the greatest angle. On the contrary, about the time of the autumnal equinox, the new moon will appear most erect, or the line joining her horns the least inclined to a vertical circle.

100. Dark part of the Moon's Disc, visible. When the moon is first seen after the change, nearly the whole of her dark hemisphere is turned towards the earth; and although this part of the moon is not immediately enlighted by the sun, yet by the reflection of the sun's light from the earth to the moon, and from the moon again to the earth, it becomes partially visible.

At the change, the moon receives light from the whole of the earth's enlightened hemisphere; but as she advances in age, she will receive less, because less of this enlightened hemisphere will be turned towards her; and this secondary light will be farther diminished, in consequence of the increased size of the illuminated part of the disc. Hence this phenomenon will entirely disappear before full moon.

101. The Earth as seen from the Moon. If the two preceding articles have been well understood, it will be obvious that the earth, as seen from the moon, will assume, in the course of a lunar month, all the phases of

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What is said of a line connecting the moon's horns, when first seen after the change, at different seasons of the year?

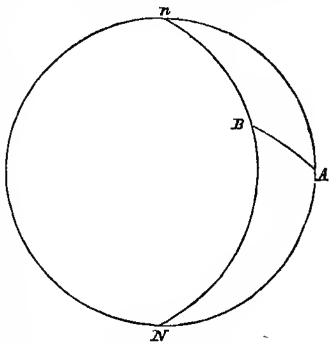
100. Explain the cause why the dark part of the moon, when first seen after the change, is partially visible. Why does this phenomenon entirely disappear before full moon?

101 What will the earth assume in the course of a lunar month, as seen from the moon?

the latter body as seen from the former. It is also evident that when it is new moon, the earth will appear to the moon a splendid full moon, thirteen times as large (98) as the moon when full appears to us. At any particular time the phase of the one body will be the opposite that of the other.

102. Inclination of the Orbit and place of the Nodes. The moon's orbit is not in the plane of the ecliptic, but is inclined in an angle varying from 5° to 5° 17′. From a series of latitudes and longitudes, determined from the moon's observed right ascensions and declinations, we find the inclination of her orbit and the place of her nodes. The greatest of these latitudes will be the inclination of the orbit; and when the latitude is zero, and changing from south to north, the longitude will be the place of the ascending node. The opposite point of the ecliptic will be the place of the descending node.

Thus, let N A *n*, represent the ecliptic, and N B *n*, the moon's orbit referred to the celestial sphere. Since the two great circles bisect each other in the points N and *n*, it is evident that the arc A B, of a great circle will measure the greatest latitude (18), when described about N as a pole, and consequently will measure the angle A N B, or the inclination of the orbit to the plane of the ecliptic. When the latitude is zero, or when the moon is at N or *n*, the longitudes will evidently be the position of the nodes. N being the ascending and *n* the descending node.



What is also evident in relation to this matter? What is said of the phase of the one body, compared with that of the other, at the same time?

102. What is the inclination of the moon's orbit to the plane of the ecliptic? From what are the inclination and place of the nodes found? Explain these principles by the diagram.

103. RETROGRADE MOTION OF THE NODES. The moon's nodes have a retrograde motion, amounting to about 19° 20′ in a year, and consequently making a complete tropical revolution in 6798 days = 18*y*. 224*d*. This variation of the nodes, which is not quite uniform, is found from their repeatedly determined longitudes.

104. SAME HEMISPHERE OF THE MOON ALWAYS SEEN, AND ROTATION ON THE AXIS. By observing attentively the moon's surface and the position of the spots thereon, we find that nearly the same hemisphere is always turned towards the earth, and hence, as she revolves in her orbit from west to east round the earth in 27*d*. 7*h*. 43*m*. 5*s*., (95) she must necessarily make a rotation on her axis from west to east in the same interval of time. Hence, also, the inhabitants (if any) of that hemisphere turned from the earth, will be deprived of a sight of this, our planet.

105. INCLINATION OF THE AXIS, SEASONS, AND DAYS. In the preceding article, we noticed that the moon always presents the same hemisphere to the earth with but slight variations. These variations are not found to arise from any want of uniformity in the motion on her axis, but from the irregularity of motion in her orbit, and the inclination of the lunar equator to the plane of the ecliptic.

From accurate observations on the slight change of position of the lunar spots, it is ascertained that the axis of the moon, which maintains its parallelism, makes only an angle of 1° 30′ with the perpendicular to the plane of the ecliptic, consequently she can have but little or no

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103. Do the moon's nodes vary? What is the amount of this variation in a year? In what time do they make a complete revolution? From what is this variation of the nodes found?

104. What will we find by observing attentively the moon's surface, and the position of spots thereon? What are the consequences of this?

105. Does the moon always present the same hemisphere to the earth without any variations? From what do these variations arise? What is the inclination of the axis, and how ascertained?

diversity of seasons, or of length of days. It is also found that the intersection of the plane of the lunar equator with the plane of the ecliptic, is always parallel to the line of the moon's nodes. And since the moon revolves on her axis exactly in the same time in which she performs her periodic revolution round the earth, it is evident, her siderial day = 27*d.* 7*h.* 43*m.* 5*s.*, hence, her solar day = 29*d.* 12*h.* 44*m.*, the length of the lunar month; and hence, also, the length of her year is but a little more than $12\frac{1}{3}$ of her solar days.

106. MOON'S LIBRATIONS. In consequence of the irregular motion of the moon in her orbit, at one time moving slower, and at another time faster, than her mean motion, small portions of her surface on the eastern and western edges, will alternately appear and disappear. This periodical oscillation observed in the spots near these edges, is called the moon's *libration in longitude.*

Also, in consequence of the inclination of the axis, and its remaining always parallel to itself, we will at one time see beyond the north pole of the moon, and at another time beyond the south pole. This alternate change in the appearing and disappearing of the lunar spots near the poles, is called the moon's *libration in latitude.*

107. ECCENTRICITY OF THE ORBIT.

When the moon is in perigee and apogee, her apparent diameters will then be the greatest and the least, which are found to vary from one revolution to another. Of these, the greatest is 33′ 31″, and least 29′ 22″. The means of the greatest and least apparent diameters for one year, are respectively about 32′ 59″.6, and 29′ 28″; hence, by using the formula in deter-

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What is the consequence of this small inclination? What are the lengths of the siderial and solar days respectively? What is the length of her year?

106. Describe the moon's libration in longitude. Describe her libration in latitude.

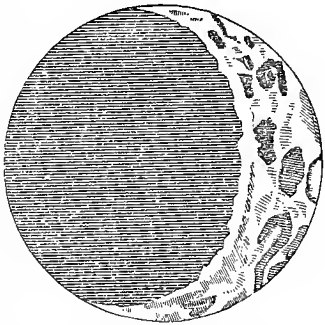
107. When has the moon the greatest and least apparent diameters? Do these vary from one revolution to another? From the means of the greatest and least apparent diameters, deduce the eccentricity of her orbit.

mining the eccentricity of the earth's orbit (85), we have

$$e = \frac{D - d}{D + d} = .056,$$ by substituting the values of D and d.

Or the perigean and apogean distances may be found from the greatest and least parallaxes (55), and the eccentricity deduced therefrom.

108. Moon's Surface and Mountains. When the moon's disc is viewed with the telescope, numerous spots are seen of various shapes and degrees of brightness. (See the figure.) The line of illumination is very irregular and serrated. Bright spots on the dark part near this line are frequently observed, which gradually enlarge until they become united with the enlightened part. From these appearances it is inferred that the surface of the moon is diversified with mountains and valleys; and since the boundary of light and darkness is always very irregular, it follows that the moon cannot have any extensive seas, otherwise this line on the surface of water would evidently be a regular curve.



The elevations of several lunar mountains have been computed. According to Dr. Herschel, the highest does not exceed $1\frac{3}{4}$ miles in altitude. Professor Schrœter makes the height of some to exceed 5 miles. Several mountain ranges have the

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By what other method may the eccentricity be found?

108. What are seen on the moon's disc, when viewed with a telescope? What is said of the line of illumination, and of spots on the dark part? What is inferred from these appearances? From what circumstance does it follow, that the moon cannot have any extensive seas? According to Dr. Herschel, what is the altitude of the highest lunar mountains? What does Schrœter make the height of some? What is said of several mountain ranges?

appearance of volcanic origin, the force of which is now believed to be extinct.

109. Moon's Atmosphere. The question, whether a lunar atmosphere exists, has long been discussed by astronomers. The constant serenity of her surface, being without clouds or vapors, the want of a sensible diminution or refraction in the light of a fixed star nearly in contact with her limb, and the want of a sensible effect on the duration of an eclipse of the sun, have induced some astronomers to maintain that the moon is without an atmosphere, at least, of such a nature, as appertains to our earth.

Notwithstanding, it is maintained by others, that the above arguments are not opposed to the existence of an atmosphere of a few miles only in height. The celebrated Selenographist, Schrœter, of Lilienthal, appears to have been successful in discovering an atmosphere, while making some observations on the crescent moon. He calculated that the height to which it is capable of affecting the light of a star, or of inflecting the solar rays, does not exceed 1 mile.

On the whole, it is inferred that the moon is most probably surrounded by a small atmosphere.

110. Phenomenon of the Harvest Moon. In north latitude, the rising of the moon nearly at the *same time* for several evenings together after the full moon, about the time of the autumnal equinox, is called the *Harvest Moon.* This comparatively small retardation in the moon's daily rising, we will now explain.

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109. What arguments are used in favor of the opinion, that the moon is without an atmosphere? Are these arguments opposed to the existence of a lunar atmosphere but a few miles in height? Who appears to have been successful in discovering an atmosphere? On the whole, what is inferred?

110. At what time does the moon rise for several evenings together, after full moon, about the time of the autumnal equinox? What is this peculiar rising of the moon called?

Since the moon's orbit coincides nearly with the ecliptic (102), her motion, in a general illustration of the phenomenon, may be regarded as in that circle. The different signs of the ecliptic, on account of its obliquity to the earth's axis, make very different angles with the horizon as they rise and set, especially in considerable latitudes. Those signs which rise with the smallest angles set with the greatest angles, and *vice versa;* and, whenever these angles are least, equal portions of the ecliptic will rise in less time, than when these angles are greater; and the contrary.

In northern latitudes, the smallest angles are made when Aries and Pisces rise, and the greatest when Libra and Virgo rise; consequently when the moon is in Pisces or Aries, she rises with the least difference of time, and she is in these signs twelve times in a year; and when she is in Virgo or Libra, she rises with the greatest difference. This peculiar rising of the moon, passes unobserved at all seasons of the year, except in the months of September and October; because in winter, when the moon is in Pisces or Aries, she rises at noon, being then in her first quarter; but when the sun is above the horizon, the moon's rising is never perceived. In spring, the moon rises with the sun in these signs, and changes in them at that time of the year; consequently, she is quite invisible. In summer, when the moon is in these signs, she

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With what circle does the moon's orbit nearly coincide? What is said respecting the different signs of the ecliptic, on account of its obliquity to the earth's axis? With what angles do those signs set, which rise with the least? When do equal portions of the ecliptic rise in less time? In northern latitudes, what signs make the smallest angles with the horizon in rising? What signs the greatest angles? In what signs is the moon, when she rises with the least difference of time? And in what when she rises with the greatest difference of time? How often is the moon in Pisces or Aries? In winter, when the moon is in these signs, at what time does she rise? What is her age then? Why is her rising not perceived? In spring, when in these signs, why is her rising invisible? In summer, why does her rising pass unobserved? And in autumn, why is this phenomenon of the moon's rising so very conspicuous?

rises about midnight, being then in her third quarter, and rising so late that she passes unobserved. But in autumn when the moon is in these signs, she rises at or about sunset, being then full, because the sun is diametrically opposite to her in Virgo or Libra, answering to the month of September or October, at which time this phenomenon of the moon's rising is very conspicuous, which had passed unobserved at all other times of the year before.

In south latitude, the smallest angles are made when Virgo and Libra rise, and the greatest when Pisces and Aries rise; so that, when the moon is in Virgo or Libra, she rises with the least difference of time; and when she is in Pisces or Aries, she rises with the greatest difference of time; but when the moon is full in Virgo or Libra, the sun is in Pisces or Aries, which is about the time of our vernal equinox, or the time of harvest in the southern hemisphere. Hence, the harvest moons are as regular in south latitude as in north latitude, but they take place at opposite times of the year.

By elevating the pole of an artificial globe for the latitude of the place, and bringing the different signs of the ecliptic to the eastern edge of the horizon, these phenomena may be fully explained and verified. In our latitude, the least difference in the moon's risings is about 25 minutes, and the greatest 1*h.* 5*m.*

111. Astronomical Sign. The astronomical sign is the crescent ☽ or the moon in her first quarter.

In south latitude, what signs make the smallest angles in rising? What signs the greatest angles? In what signs is the moon, when she rises with the least difference of time in south latitude? When is the moon full in Virgo or Libra? What season of the year is it then in the southern hemisphere?

Are the harvest moons as regular in south as in north latitude? How may these phenomena be fully explained and verified? What are the least and greatest differences in the moon's risings, in our latitude?

111. What is the astronomical sign of the moon?

CHAPTER X.

MARS.—♂

112. Remarks. Mars, the first planet without the earth's orbit, appears as a star of the first or second magnitude, and is easily distinguished from the other planets by his dusky red light. Mars is sometimes in conjunction with the sun, but he was never seen to transit the sun's disc. He appears sometimes round and full, when viewed with a good telescope, and at other times gibbous, but never horned; therefore, from these appearances, it is manifest that he shines not by his own light, and that his orbit is more distant from the sun than the earth's orbit. When Mars is in opposition, or on the meridian at midnight, his apparent size is much larger than when he is near conjunction, because in the former situation, he is but about $\frac{1}{5}$ as far from the earth as in the latter.

113. Period and Distance. Mars performs his siderial revolution round the sun in 686*d.* 23*h.* 30*m.* 37*s.* = 59355037*s.* Hence, $\left\{\frac{59355037}{31558151}\right\}^2 = 3.537461502596$;

and $\sqrt[3]{3.537461502596} = 1.5236$, the distance of Mars from the sun or semi-axis, the earth's distance being = 1. Then $1.5236 \times 24047\,r = 36638\,r$, the distance in mean radii of the earth; and $36638 \times 3956m. = 144{,}939{,}928$

112. Which is the first planet without the earth's orbit? What is the appearance of Mars, and how distinguished? Was he ever seen to transit the sun's disc? What are his appearaoces when viewed with a good telescope? What is manifest from these appearances? Why is his apparent size much larger when in opposition than when near conjunction?

113. In what time does Mars perform his siderial revolution? From this deduce his mean distance, taking the earth's mean distance equal to unity. What is his distance in miles?

miles, the mean distance of Mars from the sun. According to this distance and the periodic time, it will be found that the planet moves in his orbit at the mean rate of about 55,000 miles per hour. Also, according to this distance, the intensity of the sun's light at Mars is not half its intensity at the earth.

114. Apparent Diameter and Magnitude. The greatest and least apparent diameters of Mars, found from observations, are respectively 23″ and 3″.4. His apparent diameter will evidently be a maximum when at his perihelion distance and in opposition, and a minimum when at his aphelion distance and in conjunction; hence, $23'' + 3''.4 : 3''.4 :: 1.5236 \times 2 : .39244$, the distance of Mars from the earth when his apparent diameter is 23″. Again, $1 : .39244 :: 23'' : 9''.026$, the apparent diameter at a distance from the earth equal to that of the sun; hence, $32'\ 1''.8 : 9''.026 :: 886144m. : 4161$ miles $\doteq$ the real diameter of Mars. And $\left(\frac{4161}{7912}\right)^3 = .1454$, making the magnitude but a little more than $\frac{1}{7}$ that of the earth.

115. Eccentricity of the Orbit.

From the preceding article, the eccentricity of the planet's orbit may be calculated within a near degree of the truth. Thus, $.39244 + 1 = 1.39244$, the perihelion distance from the sun; and $\frac{1.5236 - 1.39244}{1.5236} = .086$, the eccentricity of the orbit nearly.

116. Inclination of the Orbit, &c. The inclination

At what rate per hour does he move in his orbit? What is the comparative intensity of the sun's light at Mars?

114. What is the greatest, and what is the least apparent diameter of Mars? When will he have the greatest and when the least apparent diameter?

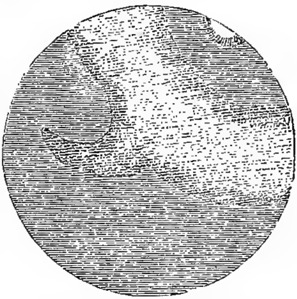
From these deduce his real diameter in miles. What is his comparative magnitude?

115. How may the eccentricity of the orbit of Mars be calculated?

116. What is the inclination of the orbit of Mars to the ecliptic, and

of the orbit of Mars to the plane of the ecliptic is 1° 51′, and the ascending node 18° in Taurus. He revolves on his axis, which is inclined to the axis of the ecliptic 30° 18′, in 24*h*. 39*m*. 21*s*. Hence, this great obliquity of his equator to the orbit, will occasion a great diversity of seasons, and a great inequality in the length of his days and nights. The great eccentricity of the planet's orbit will cause a great difference in the length of his seasons, the spring and summer in the northern hemisphere being 372, and the autumn and winter 296 martial days long.

117. TELESCOPIC APPEARANCES OF MARS. When Mars is viewed with a good telescope, spots are seen on his surface, which retain their size and form, and their appearances, with some slight variations of color. Some spots are of a reddish color, and therefore conjectured to be land, while others are greenish, and thence supposed to be water.



Remarkable white spots (see the figure) are often seen near the poles of the planet. These vary in size, and after long exposure to the sun, sometimes disappear, for which reason they are believed to be snow. From observations on these spots, the obliquity of the axis to the orbit, and the time of rotation thereon, have been found.

118. ASTRONOMICAL SIGN. The astronomical sign of Mars, ♂, represents a spear and shield, the emblems of war.

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the place of the node? What is the inclination of his axis, and the time of rotation thereon? What will this great obliquity of the equator to the orbit occasion? What will the great eccentricity of the orbit cause? What are the lengths of his seasons in martial days?

117. Give a description of the spots seen on the surface of Mars. Describe particularly the spots seen near the poles of the planet. What have been found from observations on these spots?

118. What is the astronomical sign of Mars?

CHAPTER XI.

ASTEROIDS—VESTA, JUNO, CERES, PALLAS, ASTRÆA, HEBE, FLORA, IRIS, AND METIS.

119. REMARKS. The planets Vesta, Juno, Ceres, and Pallas, of this group, sometimes called Asteroids, have been discovered about the beginning of the present century; the others, within the last three years. Although these planets are situated between the orbits of Mars and Jupiter, yet on account of their smallness, they cannot be seen without the aid of a telescope. Their orbits cross each other, though not in the same plane. There is much uncertainty concerning their actual magnitudes; and the inclinations of their axes, and rotations thereon, have not yet been determined.

It is the opinion of some philosophers, that a large planet, which once existed between the orbits of Mars and Jupiter, burst in pieces by some internal force capable of overcoming the mutual attraction of the fragments, and therefore gave rise to these small planets under consideration.

120. VESTA. The planet Vesta was discovered by Dr. Olbers, a physician of Bremen, in Germany, on the 29th of March, 1807. She revolves round the sun in 1325½ days, in an orbit inclined to the ecliptic 7° 8′, and at a mean distance of nearly 225,000,000 miles. Her diameter is estimated at only 270 miles.

121. ASTRONOMICAL SIGN. On the altar of Vesta, the goddess of fire and patroness of the vestal virgins, a per-

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119. Name the Asteroids. Where are they situated, and why can they not be seen without the aid of a telescope? What is said of their orbits? What is the opinion of some philosophers concerning their origin?

120. By whom and when was Vesta discovered? What is her period? Inclination of her orbit? Mean distance? And diameter?

121. What have astronomers adopted as her sign?

petual flame was maintained; hence astronomers have adopted an altar, ⚶ as her astronomical sign, on which a fire is blazing.

122. Juno. The planet Juno was discovered by M. Harding, of Lilienthal, near Bremen, on the 1st of September, 1804. She revolves in her orbit round the sun in 1593 days, at the mean distance of nearly 254,000,000 miles. Her orbit, which is very eccentric, is inclined to the ecliptic in an angle of 13° 2′. The diameter of Juno is stated to be 460 miles.

123. Astronomical Sign. Juno, the queen of the heavens, has for her astronomical sign, ⚵, a mirror crowned with a star, the emblems of beauty and power.

124. Ceres. Ceres was discovered at Palermo, in Sicily, by M. Piazzi, on the 1st of January, 1801. She performs her revolution round the sun in 1684 days, at a mean distance from him of about 263,000,000 miles. Her orbit, which is inclined to the ecliptic 10° 37′, is but moderately eccentric. The diameter of this planet is given equal to that of Juno, viz: 460 miles.

125. Astronomical Sign. The astronomical sign of Ceres, the goddess of corn and harvests, called Bona Dea, is a sickle, ⚳, the instrument of the harvest.

126. Pallas. Pallas was discovered at Bremen, by Dr. Olbers, the discoverer of Vesta, (120), on the 28th of March, 1802. She performs her revolution round the sun in 1686 days, at the mean distance from him of about 263,000,000 miles. The eccentricity of her orbit, which

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122. By whom and when was Juno discovered? What is her period? Mean distance? Inclination of the orbit? And diameter?

123. What is the astronomical sign of Juno?

124. By whom and when was Ceres discovered? What is her period? Mean distance? Inclination of the orbit? And diameter?

125. What is the astronomical sign of Ceres?

126. By whom and when was Pallas discovered? What is her period? Mean distance? Inclination of the orbit, and its eccentricity?

is inclined to the plane of the ecliptic 34° 35′ nearly, is ¼ the semi-axis or mean distance from the sun. Lamont has stated the probable diameter of Pallas, which is the largest of the five, to be 670 miles.

127. ASTRONOMICAL SIGN. Pallas, the reputed goddess of wisdom and war, has for her astronomical sign, ⚴, the head of a spear.

128. ASTRÆA, HEBE, FLORA, IRIS, AND METIS. Astræa, the fifth Asteroid, was discovered by Mr. Hencke, of Dresden, December 15th, 1845. This planet revolves round the sun in 1566 days, in an orbit inclined to the ecliptic 7° 45′, and at a mean distance of 253,000,000 miles.

Mr. Hencke, the discoverer of Astræa, discovered, on the 1st of July, 1847, the sixth Asteroid, called Hebe. It resembles in appearance a star of the ninth magnitude. Mr. Hind, secretary of the Royal Astronomical Society, England, soon after the discovery of Hebe, added Flora and Iris to the same family group. And lastly, on the 25th of April, 1848, Mr. Graham, of Mr. Cooper's Observatory, Markee Castle, Sligo, discovered Metis, the ninth Asteroid. The elements of these four planets have not yet been computed with sufficient accuracy, to warrant their record. Several other Asteroids may exist.

129. ASTRONOMICAL SIGN OF ASTRÆA. A star, *, is the astronomical sign of Astræa, the goddess of justice.

130. ULTRA-ZODIACAL PLANETS. The great inclinations of the orbits of Juno, Ceres, and Pallas, to the plane

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How does Pallas compare in magnitude with the other asteroids? What is her diameter according to Lamont?

127. What is the astronomical sign of Pallas?

128. What is said of Astræa? By whom discovered, and when? What is her period? Inclination of the orbit? And mean distance? Who discovered Hebe, and when? Who discovered Flora and Iris? When was Metis, the ninth Asteroid, discovered and by whom?

129. What is the astronomical sign of Astræa?

130. What planets are called ultra-zodiacal, and on what account?

of the ecliptic, being respectively 13° 2′, 10° 37′, and 34° 35′, will cause that they are found, sometimes, beyond the limits of the zodiac (10); and hence they are called *ultra-zodiacal* planets.

CHAPTER XII.

JUPITER—♃—AND HIS SATELLITES.

131. Remarks. Jupiter, the largest of all the planets, and the most brilliant in appearance, except sometimes Venus, may, on those accounts, be distinguished by his great magnitude and peculiar brightness. When Jupiter is opposite to the sun, that is, when he comes to the meridian at midnight, he is then nearer to the earth than he is for some time before or after conjunction; and consequently, at the time of opposition, he appears larger and shines with greater lustre than at other times. Sometimes Jupiter appears nearly as large as Venus, though his nearest distance from the earth is fifteen times the nearest distance of Venus from our planet.

132. Period and Distance. Jupiter performs his siderial revolution round the sun in 4332*d.* 14*h.* 2*m.* 8*s.* = 11*y.* 314*d.* 22*h.* of our time, which reduced, is 374335328*s.* Hence, $\left[\frac{374335328}{31558151}\right]^{\frac{2}{3}} = 5.202$, the semi-axis of the orbit, supposing the earth's mean distance equal unity.

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131. Which is the largest of all the planets? How may Jupiter be distinguished? When does he appear larger, and shine with greater lustre, than at other times. What is said of his appearance sometimes, compared with the appearance of Venus?

132. What is the time of Jupiter's siderial revolution? From the siderial revolution, deduce the semi-axis of his orbit.

Therefore, 95,129,932$m.$ $\times$ 5.202 $=$ 494,865,906 miles, the mean distance of Jupiter from the sun. And 4332$d.$ 14$h.$: 1$h.$: : 494,865,906$m.$ $\times$ 2 $\times$ 3.1416 : 30,600 miles nearly, the hourly mean motion of Jupiter in his orbit. Also, $(5.202)^2 = 27$, which shows that the intensity of the sun's light at Jupiter is but $\frac{1}{27}$ of its intensity at the earth.

133. Apparent Diameter and Magnitude. According to the best observations, Jupiter's apparent diameter when in opposition, is 45″.9; hence 1 : 5.202 — 1 : : 45″.9 : 192″.87 = Jupiter's apparent diameter at a distance from the earth equal to that of the sun. Again, 32′ 1″.8 : 192″.87 : : 886,144$m.$: 88,932 miles, the real diameter of Jupiter. And

$$\left[\frac{88932}{7912}\right]^3 = (11.2)^3 \doteq 1404.928,$$ which shows that Jupiter's volume is about 1400 times that of the earth.

134. Inclination of the Orbit, etc. Jupiter's orbit is inclined to the ecliptic 1° 18′ 51″, and the ascending node is 8° 26′ in Cancer. He revolves on an axis, which is nearly perpendicular to the plane of his orbit, in 9$h.$ 55$m.$ 50$s.$ Jupiter is much more flatted at the poles than the earth. This oblateness, which is stated to be $\frac{1}{14}$ of his equatorial diameter, is owing to his great magnitude, and the rapidity with which he revolves on his axis.

Since the axis is nearly perpendicular to the orbit, his equator and orbit will nearly coincide; hence, he will have no di-

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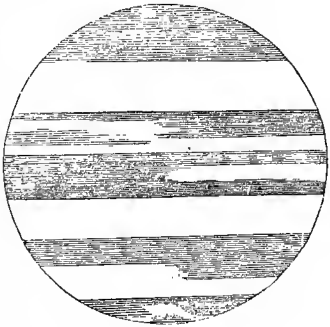
What is his mean distance in miles? From the mean distance, find his hourly mean motion in the orbit. What is the comparative intensity of the sun's light at Jupiter?

133. What is the apparent diameter of Jupiter when in opposition? From this, determine his apparent diameter at a distance equal to that of the sun, and thence his real diameter. What is his volume, compared with that of the earth?

134. What is the inclination of the orbit of Jupiter, and the place of the node? What is the inclination of his axis to the plane of the orbit? In what time does he revolve on his axis? What is said of the great oblateness of the planet, and to what is it owing?

versity of seasons, and no change in the length of the days and nights. It has been shown (132) that the intensity of the sun's light at Jupiter, is only $\frac{1}{27}$ of its intensity at the earth; but the quick returns thereof, and the four satellites which attend him, compensate for the deficiency.

135. Belts of Jupiter. When Jupiter is viewed through a telescope of sufficient magnifiying power, his disc is observed to be crossed by obscure stripes or bands, which, although always parallel to the equator of the planet, are subject to many changes both as to appearances and number. These are called the Belts of Jupiter. (See the figure.)



The belts sometimes retain the same appearances for several months, but occasionally marked changes take place in them in the course of a few hours. Dark spots have often been seen on these belts, by the motion of which the planet's rotation has been ascertained.

Various opinions have been entertained concerning the cause of the belts of Jupiter. They are generally supposed to be the body of the planet seen through interstices of a cloudy atmosphere, caused by the great velocity of the diurnal motion of the planet. The spots are supposed to be on the body of the planet, and to become visible only when immediately below one of these interstices.

136. Astronomical Sign. The astronomical sign of

Why has he no divesity of seasons, and no change in the length of the days and nights?

135. Describe the belts of Jupiter. What have often been seen on these belts, and what ascertained from their motion? What are the belts generally supposed to be? What, the spots?

136. Describe the astronomical sign of Jupiter.

Jupiter, ♃, appears to be a modification of the letter Z, the initial of *Zeus*, the name of Jupiter among the Greeks.

137. SATELLITES OF JUPITER. Jupiter has four satellites or moons, which revolve round him in short periods of time, and at corresponding small distances from him. These satellites are invisible to the naked eye, but they can be seen through a telescope of moderate power. Galileo, the inventor of telescopes, discovered them in the year 1610. Their orbits, which are nearly circular, coincide very nearly with the equator of Jupiter; and since his equator is nearly in the plane of his orbit, which makes but a small angle of inclination (134) with the plane of the ecliptic, it follows that they cannot deviate far from the last plane, and therefore they will always appear nearly in a straight line with each other.

138. PERIODS AND DISTANCES.

The siderial revolutions of Jupiter's satellites round their primary, and their distances from him, are as follow:

SAT.		D.	H.	M.	S.		MILES.
1,	siderial rev.	1	18	27	35	dist. from J.	269,159
2,	" "	3	13	13	42	" " "	428,244
3,	" "	7	3	42	33	" " "	683,085
4,	" "	16	16	32	8	" " "	1,201,426

139. MAGNITUDES, ETC., OF JUPITER'S SATELLITES.

According to La Place, the apparent diameter of the first, as seen from the centre of Jupiter, is 30′ 21″, which is nearly equal to the moon's mean apparent diameter (98); and since its distance from the primary is 269,159 miles, a distance about $\frac{1}{8}$ more than the distance of the moon (97) from the earth, we conclude that it is but a little larger than the former of these bodies. The second satellite is nearly the size of the

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137. How many satellites has Jupiter? By whom were they discovered, and when? With what circle do their orbits nearly coincide, and what follows from this?

138. Give the siderial revolution and distance of the first satellite of Jupiter. Of the second? Third? And fourth?

139. Why do we conclude that the first satellite of Jupiter is but a little larger than our moon? What is the size of the second?

first; the third is considerably the largest of the four; and the fourth a little larger than the first. According to Dr. Herschel, each satellite turns on its axis in the same time in which it revolves round the planet; and hence, like our moon, (104) always presents the same face to the primary.

140. Eclipses of Jupiter's Satellites. The orbits of Jupiter's satellites are nearly in the plane of that of the primary, hence these bodies will frequently pass through Jupiter's shadow, and be *eclipsed.* Since their orbits differ but little from circles (137), their true elliptical motions will be nearly equal to their mean motions; and since their periodic revolutions are extremely short, and therefore affording frequent opportunity for making observations on their motions, astronomers have been enabled to construct tables for determining the time of their eclipses with wonderful accuracy. The tables of De Lambre on this subject are considered the most correct.

141. The Longitudes of Places determined by the Eclipses of Jupiter's Satellites. The same immersion of one of these Satellites into, or emersion out of, the shadow of Jupiter, will be perceived at the same instant of time at different parts of the earth; hence, if the times of immersion or emersion be noticed at different places, the difference of these times converted into degrees will be the difference of longitude between the two places. The first satellite, or that nearest to Jupiter, is the most important of the four for this purpose, because

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Of the fourth? Which is considerably the largest of the four? According to Dr. Herschel, in what time does each turn on its axis? What follows from this?

140. Why are Jupiter's satellites frequently eclipsed? What circumstances have enabled astronomers to construct tables for determining the time of their eclipses with wonderful accuracy? Whose tables on this subject are considered the most correct?

141. Show distinctly how the difference of longitude between two places may be found by the eclipses of Jupiter's satellites. Which is the most important of the four for this purpose, and why?

on account of its quick motion, its immersions and emersions will be almost instantaneous ; and also, on account of the shortness of its synodic revolution, its eclipses will be very frequent.

The times of the eclipses of Jupiter's satellites, computed from tables for this purpose, are given in the "Nautical Almanac," and calculated for the meridian of Greenwich. Now let an observer at any place, with a good telescope, observe the beginning or end of one of these eclipses, and note, by means of a pendulum clock which beats seconds or half-seconds, the precise time when he saw the satellite immerge into, or emerge out of, the shadow of Jupiter; the difference between this time and that given in the Almanac, will be the difference of time between Greenwich and the place of observation; hence the true longitude of the latter from the former is easily obtained. These eclipses will not serve for determining the longitude of a ship at sea, because the rolling of the vessel prevents that exactness required for such observations.

142. The Velocity of Light determined by means of the Eclipses of Jupiter's Satellites. Rœmer, a Danish astronomer, in the year 1667, discovered the progressive motion of light by a comparison of observations made on the eclipses of Jupiter's satellites. This astronomer found that when Jupiter was in opposition, or nearest to the earth, the eclipses of his satellites were seen some minutes sooner than they should be seen according to the average intervals of consecutive eclipses; and when Jupiter was near conjunction, or farthest from the earth, they were seen as much later. Hence, he concluded that these deviations depend on the distance of

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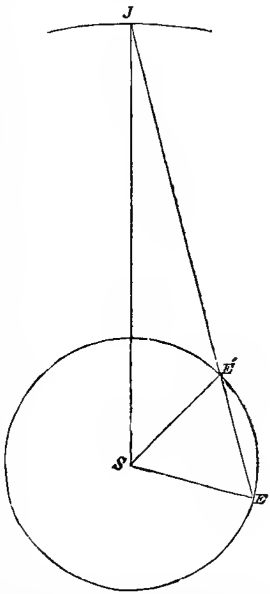
How may the longitude of any place from Greenwich be obtained by these eclipses? Why cannot the longitude of a ship at sea be determined by them?

142. Who discovered the progressive motion of light, and by what means? What did Rœmer find respecting these eclipses when Jupiter was in opposition? And what when near conjunction?

the planet from the earth, and thence, that the transmission of light, formerly thought to be instantaneous, is uniformly progressive, or that a measurable interval of time elapses between the actual occurrence of any very distant phenomenon, and the perception of it by the observer.



Let S represent the sun, E the earth, and J Jupiter, making the angle S E J = 60° = the sun's advance of Jupiter in longitude. Join E′, the point where the line E J cuts the earth's orbit and S; it is evident that the triangle S E E′ is equilateral, and that the difference between the earth's distance from Jupiter when at E, and that when at E′, is equal E E′ = S E, the distance of the earth from the sun. Now it is found that the eclipses will be seen 8*m*. 13*s*. sooner when the earth is at E′, than when at E; and hence, 8*m*. 13*s*. : 1*s*. :: 95,129,932*m*. : 192961 miles, the amazing velocity of light per second of time. If we commence our observations at any time when the longitude of the sun exceeds that of Jupiter, 60°, we can easily find how long it will require the earth to pass from E to E′ or through 60° of its orbit. This will be found about 61 days, but during this interval, Jupiter will have advanced about 5° in his orbit, and therefore this time, increased one or two days, will bring the earth as near Jupiter as if he were stationary.

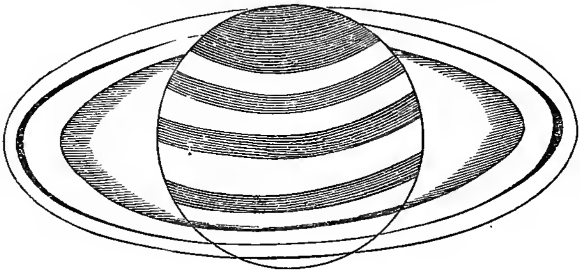
What was his conclusion respecting these deviations? Draw the figure, and show how the velocity of light is found. What is its velocity per second of time? What is said respecting the longitude of the sun and Jupiter, when we commence our observations? How much nearer to Jupiter will the earth be 62 or 63 days after this time? Who has subsequently confirmed this theory of the transmission of light?

Dr. Bradley, a celebrated English astronomer, has subsequently confirmed this theory of the transmission of light, by his discovery and explanation of the aberration of light; and as both these phenomena are connected with the orbitual revolution of the earth, they afford a clear proof of its *annual motion.*

CHAPTER XIII.

SATURN—♄—HIS SATELLITES AND RINGS.

143. Remarks. Saturn, on account of his great distance from the sun compared with the earth's distance, appears nearly of a uniform magnitude in every position; and on account of his great size, he nearly equals the apparent magnitude of Mars, when this planet is nearest to the earth. Saturn shines with a pale, faint light. He is the most distinguished planet of the solar system, being



What did Dr. Bradley discover? What is said respecting these phenomena, the transmission and aberration of light?

143. Why does Saturn appear nearly of a uniform magnitude in every position? How does his apparent magnitude compare with that of Mars when this planet is nearest to the earth? What is the color of his light? On what account is he the most distinguished planet of the solar system?

not only attended by seven satellites, but encompassed by a broad, thin ring, which is composed of two concentric rings detached from each other, without touching him, like the wooden horizon of an artificial globe. (See the figure.)

144. Period and Distance. Saturn performs his siderial revolution round the sun in 10759*d.* 5*h.* 16*m.* 30*s.* = 29 years, 167 days; hence,

$$\left\{\frac{10759.2198}{365.2564}\right\}^{\frac{2}{3}} = (29.4566)^{\frac{2}{3}} = (867.69128356)^{\frac{1}{3}} = 9.54$$

nearly = the semi-axis of the orbit, the earth's mean distance being = 1; therefore, 95129932*m.* × 9.54 = 907,539,551 miles, the mean distance of Saturn from the sun. And 10759*d.* 5*h.* : 1*d.* : : 907,539,551*m.* × 2 × 3.1416 : 22082 miles, the hourly mean motion of Saturn in his orbit. Also $(9.54)^2 = 91$, which shows that the intensity of the sun's light at Saturn is but $\frac{1}{91}$ of its intensity at the earth.

145. Apparent Diameter and Magnitude. The apparent diameter of Saturn when at his mean distance from the sun, and in opposition, is about 18″.2; hence, 1 : 9.54—1 : : 18″.2 : 155″.428 = the apparent diameter of Saturn when at a distance from the earth equal to that of the sun. Then 32′ 1″.8 : 155″.428 : : 886144*m.* : 71668 miles, the diameter of Saturn; and, $\left\{\frac{71668}{7912}\right\}^3$ $= (9.06)^3 = 744$, which shows how many times Saturn's volume is greater than that of the earth.

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144. In what time does Saturn perform his siderial revolution? From this determine the semi-axis of his orbit, and his mean distance in miles. What is his hourly mean motion in the orbit? What is the intensity of the sun's light at Saturn, compared with its intensity at the earth?

145. What is the apparent diameter of Saturn when at his mean distance from the sun, and in opposition? What is his real diameter in miles, and how found? How many times is his volume greater than that of the earth?

146. Inclination of the Orbit, &c. The inclination of the orbit of Saturn to the plane of the ecliptic is 2° 29′ 36″, and the ascending node 22° in Cancer. He revolves in 10*h*. 29*m*. 17*s*. on an axis which is inclined about 29° to the axis of the orbit. The oblateness of this planet is about $\frac{1}{11}$, or the polar diameter is $\frac{1}{11}$ less than the equatorial diameter.

147. Astronomical Sign. The astronomical sign of Saturn is ♄, supposed to represent the original form of a sythe with which he was armed, an emblem of the ravages of time.

148. Satellites of Saturn. It has been already observed, that Saturn is attended by no less than seven satellites or moons, which supply him with light during the sun's absence. The 6th of these satellites in the order of their distances from the primary, was discovered by Huygens, a Dutch mathematician in the year 1655. The 3d, 4th, 5th, and 7th, were discovered by John Dominic Cassini, a celebrated Italian astronomer, between the years 1671 and 1685. The 1st and 2d, were discovered by Dr. Herschel in the years 1787 and 1789. Large telescopes are required for the observations of these satellites, particularly the 1st and 2d, the discovery of which was a fruit of Dr. Herschel's large reflecting telescope of 40 feet focus. The times of their revolutions round Saturn and their respective distances from him, are as follows:

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146. What is the inclination of the orbit of Saturn to the ecliptic, and the place of the node? In what time does he revolve on his axis? What is the inclination of his axis to the axis of the orbit? What is the oblateness of this planet?

147. Describe the astronomical sign of Saturn. Of what is it an emblem?

148. How many satellites attend Saturn? By whom, and when was the 6th discovered? By whom, and when, were the 3d, 4th, 5th, and 7th discovered? By whom, and when, were the 1st and 2d discovered? What is said of the telescopes required for the observations of these satellites, particularly the 1st and 2d?

SAT.			D.	H.	M.	S.			MILES.
1	sid.	rev.	0	22	37	23	dist.	from S.	120,000
2	"	"	1	8	53	9	"	"	154,000
3	"	"	1	21	18	26	"	"	189,000
4	"	"	2	17	44	51	"	"	244,000
5	"	"	4	12	25	11	"	"	341,000
6	"	"	15	22	41	13	"	"	791,000
7	"	"	79	7	54	37	"	"	2,306,000

149. MAGNITUDES, &c.

The satellites of Saturn, owing to their great distance from us, appear very small, and consequently, their real magnitudes are not well known. The 7th is the largest, and according to Sir John Herschel, is nearly equal in size to the planet Mars. From the 7th, or most distant, they are said to diminish inward.

The orbits of the satellites are in the plane of Saturn's ring, except that of the 7th, which is considerably inclined to it; and since the ring coincides with the planet's equator, which latter plane makes an angle of 29° (146) with Saturn's orbit, it follows that they will be but seldom eclipsed, and only when Saturn is in or near one of the nodes of their orbits.

As the 7th satellite exhibits periodical variations of brightness, it is inferred, that like our moon, it rotates on an axis in the same time that it revolves round Saturn.

150. SATURN'S RINGS. Huygens first discovered Saturn's ring, which Dr. Herschel afterwards, by the assistance of his powerful telescopes, found to be double, or to consist of two concentric rings. The ring casts a shadow on the planet, and is likewise obscured on that side opposite to the sun by the planet's shadow; hence, the general conclusion is that it is a solid opaque body, shining by reflecting the light of the sun.

Give the times of their revolutions round Saturn, and their respective distances from him.

149. Why are the magnitudes of Saturn's satellites not well known? Which is the largest, and what is its size according to Sir John Herschel? Explain the reason why they are but seldom eclipsed. What is inferred from the periodical change of brightness observed in the 7th?

150. Who first discovered Saturn's ring? Who afterwards found it to be double? What is the general opinion respecting the nature of the

It has been observed, that this most extraordinary appendage is very thin. According to Sir John Herschel, its thickness does not exceed 100 miles. From the micrometrical measurements of Professor Struve, the other dimensions are as follows :

Interior diameter of the interior ring, -	117,000	miles
Distance of the edge of the interior ring from the planet, - - - -	20,000	"
Exterior diameter of the interior ring, -	151,000	"
Breadth of the interior ring, - - -	17,000	"
Interior diameter of the exterior ring, -	155,000	"
Interval between the rings, - -	2,000	"
Exterior diameter of the exterior ring, -	176,000	"
Breadth of the exterior ring, - -	10,500	"

The interval between the rings can only be seen by telescopes of great power. It appears under the form of a black line, as represented in the figure (143).

151. Inclination and Rotation of the Rings. From observations, it has been found that the plane of the rings coincides with the plane of Saturn's equator, and therefore is inclined to the plane of the orbit 29°. The ascending node of the ring is 20° in Virgo. From the motion of lucid spots on the surface of the ring, it has been inferred that it rotates on an axis perpendicular to its plane, and passing through the centre of the planet. The time of this rotation, which is from west to east, is 10*h*. 29*m*., equal the time of Saturn's rotation on his axis.

152. Apparent Forms of the Rings. Since the plane of the ring, which continues parallel to itself, is inclined to the orbit under an angle of about 28° 40′;

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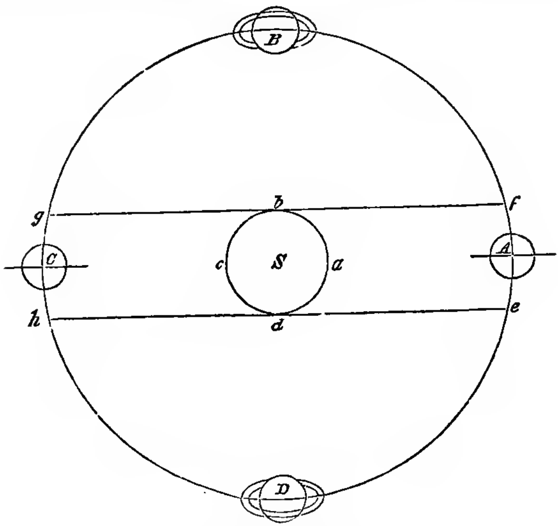
ring, and on what based? What is the thickness of the ring according to Sir John Herschel? From the micrometrical measurements of Professor Struve, what are the other dimensions?

151. What is said respecting the inclination of the ring, and the place of the ascending node? What has been inferred from the motion of lucid spots on its surface? What is the time of this rotation?

152. Explain the reason why Saturn's ring appears elliptical.

and since this latter plane nearly coincides with the ecliptic (146), it follows that it can never be seen from the earth but under different degrees of obliquity, varying from about 60° to 90° with its axis; hence, it will not appear circular in its form, which it really is, but elliptical. And as the orbit of Saturn is very large, compared with the earth's orbit, the eccentricity will vary according to the distance of the planet from one of the nodes of the ring.

Let S represent the sun, *a b c d* the orbit of the earth, and A B C D the orbit of Saturn. If A and C be the nodes of the ring, it is evident that when the planet is at A or C, the plane of the ring will pass through the sun, and hence, the edge will only be illuminated. In this position, the ring can only be seen with a telescope of high power, appearing like a line of light on the disc of the planet, and extending some distance on each side of it.



According to what will its eccentricity vary? Draw the diagram, and show the different apparent forms of the ring.

As the planet advances in the orbit from A or C, the illuminated plane of the ring will become more visible; and when at B or D 90° from the node A or C, the ring will appear most open, or to the greatest advantage.

153. Disappearances of the Ring.

If the tangent parallels *e h* and *f g* (see the last figure) be drawn at an equal distance from the node A, it will be found, taking the diameter of the earth's orbit equal 2, and Saturn's distance from the sun equal 9.54 (144), that the arc *e f* will contain 12° very nearly. Now since the planet revolves round the sun in 29 years, 167 days (144), he will pass through the portion *e f* or *g h* in nearly one year, or while the earth passes through the whole orbit, *a b c d*. This being understood, it is evident there will be occasional disappearances of the ring from the fact that the earth will sometimes be on the dark side of the plane of the ring, or on the opposite side from the sun.

Thus, if the planet come to *e*, when the earth is at any position between *c* and *d*, it is evident that in some position between *e* and A, the plane of the ring will pass between the sun and the earth, and therefore there will be a disappearance. When the planet has arrived at A, the earth will be at some position between *a* and *b*, immediately after which time there will be another disappearance, which will continue until the earth comes to a position between *b* and *c*, or on the same side of the plane of the ring with the sun. In like manner there will be occasional disappearances of the ring, when the planet is passing through the portion *g h* of the orbit. When Saturn's longitude is within 6° of either node of the ring, or within 6° of 170°, or 350° (151), one of these disappearances may be expected; and as the planet revolves round the sun in 29 years 167 days, about 14½ years will elapse from the occurrence of a disappearance at one node till another takes place at the opposite node. The last disappearance happened in April, 1848, the next will occur in 1863. When the planet's longitude is 80° or 260°, the ring will be in a position most advantageous for observation.

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153. Draw the tangent parallels *e f* and *g h* in the last figure, and show from what fact there will be occasional disappearances of the ring. Give the different positions of the planet and the earth, when these disappearances will occur. When may a disappearance be expected? When a disappearance has occurred at one node, what time will elapse before

CHAPTER XIV.

URANUS—♅—AND HIS SATELLITES.

154. Remarks. Uranus was discovered on the 13th of March, 1781, by Dr. Herschel, who named it *Georgium Sidus*, through respect to his patron, King George III. On the continent, it was generally called *Herschel*, in honor of its illustrious discoverer, and of late, astronomers have adopted the name *Uranus*, from the circum stance that the other planets have been named after heathen deities. Uranus, though large, on account of his great distance from the sun, can scarcely be distinguished by an unaided eye, even in a clear night, and in the moon's absence.

155. Period and Distance. Uranus performs his siderial revolution round the sun in 30686*d.* 19*h.* 42*m.* = 84 years, 6½ days, of tropical mean time, and hence,

$$\left(\frac{30686.821}{365.2564}\right)^{\frac{2}{3}} = (84.014469)^{\frac{2}{3}} = (7058.431)^{\frac{1}{3}} =$$

19.18239 = semi-axis of the orbit, the earth's mean distance being =1 ; therefore 95,129,932*m.* × 19.18239 = 1,824,819,456 miles, the mean distance of Uranus from the sun. And 30686*d.* 19¾*h.* : 1*h.* : : 1824819456*m.* × 2 × 3.1416 : 15567 miles, the planet's hourly mean motion

another occurs at the opposite node? When did the last disappearances happen? When will the next? What is the planet's longitude, when is the ring in a position most advantageous for observation?

154. When, and by whom was Uranus discovered? What name did Herschel give it? What was it called on the continent? From what circumstance have astronomers adopted the name Uranus? Can Uranus be distinguished by the unaided eye?

155. In what time does Uranus perform his siderial revolution? What is the length of the semi-axis of his orbit? What is his mean distance from the sun in miles? What is the planet's hourly mean motion in the orbit?

in the orbit. The intensity of the sun's light at Uranus is but $(\frac{1}{19.18239})^2 = \frac{1}{368}$ of what it is at the earth.

156. Apparent Diameter and Magnitude. The apparent diameter of Uranus when at his mean distance from the earth, is 4″, and when in opposition, it is about 4″.1; hence 1 : 19.18239 — 1 : : 4″.1 : 74″.5478, the apparent diameter of Uranus at a distance from the earth equal to that of the sun. Then 32′ 1″.8 : 74″.5478 : : 886,144*m.* · 34,374 miles, the real diameter of Uranus; and $(\frac{34374}{7912})^3 = (4.344)^3 = 82$, which shows how many times his magnitude is greater than that of the earth.

157. Inclination of the Orbit, &c. The inclination of the orbit of Uranus to the plane of the ecliptic, is but 46′ 28″, and the ascending node 13° in Gemini. Uranus doubtless revolves on an axis as the other planets do, but owing to his very great distance from us, astronomers have not been able to detect spots or any periodical changes on his surface, by which they might determine the period of his rotation. La Place was of the opinion that the time of his diurnal motion is but little less than that of Jupiter or Saturn (134, 146), and that his axis is nearly perpendicular to the plane of the ecliptic.

158. Astronomical Sign. Uranus has for his astronomical sign, ♅, the initial of the discoverer's name, with a ball, the emblem of a planet, suspended from its cross-bar.

159. Satellites of Uranus. Uranus is attended by six satellites, all of which were discovered by Dr. Her-

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What is the comparative intensity of the sun's light at Uranus?

156. What is the apparent diameter of Uranus when in opposition? From this deduce the real diameter. Also the comparative magnitude.

157. What is the inclination of the orbit of Uranus to the plane of the ecliptic, and the place of the node? What is said respecting the period of his rotation? What was La Place's opinion on this subject?

158. Describe the astronomical sign of Uranus.

159 How many satellites attend Uranus? By whom were they dis-

schel, to whose genius we are indebted for the discovery of the planet itself. The second and fourth were detected in 1787, and the other four in 1798. They are discernible only with telescopes of the highest power. Their siderial revolutions round Uranus, and their respective distances from his centre, are as follows:

SAT.		D.	H.	M.	S.		MILES.
1	sid. rev.	5	21	25	0	dist. from U.	225,000
2	" "	8	16	56	5	" "	292,000
3	" "	10	23	4	0	" "	341,000
4	" "	13	11	8	59	" "	391,000
5	" "	38	1	48	0	" "	782,000
6	" "	107	16	40	0	" "	1,564,000

These satellites are said to move in orbits nearly circular, and lying in the same plane, which is nearly *perpendicular* to the ecliptic, a remarkable peculiarity, being inclined about 79° to that plane. Their motion is *retrograde*, or contrary to the order of the signs, another singular anomaly, as all the other planets and satellites move from west to east, or according to the order of the signs. Their magnitudes cannot be less than those of the satellites of Saturn, probably greater, otherwise they could not be seen at a distance so immense from our planet. The plane in which these satellites move will pass through the sun but twice in the course of a year of Uranus, hence they can be eclipsed only at intervals of 42 years. In these eclipses, the satellites will be seen to ascend from the shadow of the planet, in a direction nearly perpendicular to the orbit

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covered, and when? Give the times of their siderial revolutions round the primary, and their respective distances from him. What is said of their orbits? Their motion? Their magnitudes? And their eclipses?

CHAPTER XV.

NEPTUNE.

160 REMARKS. All the planets not only gravitate to the sun, but to one another, hence their motions are affected by these attractions of gravitation. From the known elements of the orbit of a planet, and the attractive influence of all the other known planets, its place can be previously calculated for a certain time, and consequently compared with its place found by observation at that time. It was found that the observed places of Uranus did not agree with those determined by calculation, and hence some observing astronomers, most conversant with this subject, were led to believe that these perturbations in the motions of Uranus were produced by the action of a still more distant planet.

M. Le Verrier, a French astronomer, on the 31st of August, 1846, in his third paper on this interesting subject, made known the elements of the orbit of the supposed planet, and the method by which he arrived at the value of the unknown quantities. Le Verrier "leaves an impression on the mind of the reader, by the undoubting confidence which he has in the general truth of his theory, by the calmness and clearness with which he limited the field of observation, and by the firmness with which he proclaimed to observing astronomers, 'Look in the place which I have indicated, and you will see the planet well.'"* On the 23d of September follow-

* Mr. Airy's lecture before the Royal Ast. Soc., England.

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160. From what data can the place of a planet be calculated for a certain time, that its place may be compared with that found by observation at the same time? Did the observed places of Uranus agree with those found by calculation? What were some astronomers led to believe in consequence of the perturbations of Uranus? Who made known the elements of the supposed planet, and when? What did Le Verrier proclaim to observing astronomers?

ing, these directions of Le Verrier reached Dr. Galle, of the Berlin Observatory, and guided by them, he discovered the expected new planet on the evening of the same day.

It is but justice to notice that Mr. Adams, of St. John's College, Cambridge, in England, without any previous knowledge of M. Le Verrier's labors, had made calculations on this subject, and had arrived at similar conclusions, in consequence of which, Professor Challis, of Cambridge Observatory, was searching for the planet, when, on the 29th of September, having received the more pointed directions of the French astronomer, he changed his plan of observing, and on that evening discovered a star with a visible disc, which was the new planet. The planet at first was named Le Verrier, in honor of its distinguished discoverer, but it has since received the name of Neptune, which meets with the more general approbation and assent of astronomers.

161. Period, Distance, &c. The elements of the orbit of the new planet as made known by M. Le Verrier, previous to discovery, are, periodic time, 217 years, mean distance, or semi-axis major, 33, the earth's distance being unity; hence, 95,129,932 *m.* $\times$ 33 = 3,139,-287,756 miles, the mean distance from the sun. Eccentricity, .10761, longitude of perihelion, 284° 45', mean longitude, Jan. 1, 1847, 318° 47', and mass .0001075, or twice the mass of Uranus.

The period obtained from observation since discovery, is 167 years, and distance 30. These discrepancies in the elements have led some astronomers, and particularly, Professor Peirce, of Cambridge, Mass., to believe that Neptune is not the planet

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Guided by these directions, who discovered the new planet, and when? Who made calculations on this subject, and arrived at similar conclusions What was the new planet called at first? What name since received?

161. What are the elements of the new planet, as made known previous to discovery? What the period and distance, obtained from observation, since discovery? What have these discrepancies led some astronomers to believe?

of *theory*, but of *accident*, or that "*the planet Neptune is not the planet to which geometrical analysis had directed the telescope.*" The astronomical sign of Neptune, if one has been adopted, has not come to our knowledge.

162. Bode's Law of the Planetary Distances. Professor Bode, a German philosopher, towards the end of the last century, from a close examination of the known distances of the planets from the sun, discovered the following empirical law, namely:

assume	0	3	6	12	24	48	96	192
add	4	4	4	4	4	4	4	4
results	4	7	10	16	28	52	100	196

The terms of the last series, beginning with Mercury, will very nearly express the proportional distances of the planets of our system from the sun, thus:

Mercury.	Venus.	Earth.	Mars.	Asteroids.	Jupiter.	Saturn.	Uranus.	Neptune.
4	7	10	16	28	52	100	196	388

The great interval between the orbits of Mars and Jupiter, led Kepler to conjecture that there must be a planet revolving in the intermediate space. This curious law of the planetary distances, induced some astronomers, about the beginning of the present century, to make diligent search for the supposed planet. Four very small planets were soon discovered as the result of their labors (119). Since 1845, five more have been added to the same family group.

163. Tables relative to the Sun, Moon, and Planets.

The following tables contain the principal elements of the planetary orbits. Also, the diameters, volumes, masses, &c., of the sun, moon and planets.

Give the remark of Professor Peirce on this subject.

162. Explain Bode's law of the planetary distances? What was Kepler's conjecture, and what led to it?

Planet's Name.	Siderial Period. D.	H.	M.	S.	Semi-axis maj.	Mean distance from the sun in miles.	Inten'y of light.
Mercury,	87	23	15	43	.387099	36,824,000	6.677
Venus,	224	16	49	10	.723332	68,810,000	1.911
Earth,	365	6	9	12	1.000000	95,130,000	1.000
Mars,	686	23	30	37	1.523600	144,940,000	.431
Asteroids (P)	1686	7	19	12	2.772600	263,000,000	.130
Jupiter,	4332	14	2	8	5.202776	494,866,000	.037
Saturn,	10759	5	16	30	9.538786	907,540,000	.011
Uranus,	30686	19	42	—	19.182390	1824,819,000	.003
Neptune,	167 years,				30,000000	2853,900,000	.001

Planet's Name.	Inclin. of orbit to the Ecliptic. °	′	″	Long. of the Ascend'g Node. °	′	″	Eccentricity of the Orbit.	Mean daily motion in Long. °	′	″
Mercury,	7	0	9	45	57	31	.2055150	4	5	33
Venus,	3	23	28	74	51	55	.0068607	1	36	8
Earth,							.0167835	0	59	8
Mars,	1	51	6	48	0	3	.0933070	0	31	27
Asteroids(P)	34	35	49	172	38	30	.2419980	0	12	49
Jupiter,	1	18	51	98	26	19	.0481621	0	4	59
Saturn,	2	29	36	111	56	37	.0561505	0	2	1
Uranus,	0	46	28	72	59	35	.0466108	0	0	42
Neptune,							.1076100	0	0	21

Planet's Name.	Apparent diameter at Mean Dis. ′	″	Real Diam in Miles.	Volume.	Mass.	Rotation on the Axis. D.	H.	M.	S.
Mercury,	0	6.5	3034	0.057	$\frac{1}{2025810}$		24	5	28
Venus,	0	16.6	7654	0.905	$\frac{1}{401211}$		23	21	7
Earth,			7912	1.000	$\frac{1}{355000}$		23	56	4
Mars,	0	5.8	4161	0.145	$\frac{1}{2680337}$		24	39	21
Ast's.(P)			670						
Jupiter,	0	36.9	88932	1404.928	$\frac{1}{1048}$		9	55	50
Saturn,	0	16.2	71668	744.000	$\frac{1}{3500}$		10	29	17
Uranus,	0	3.9	34374	82.000	$\frac{1}{17918}$				
Neptune,		•							
Sun,	32	1.8	886144	1404928.000	1	25	10	0	0
Moon,	31	7	2162	0.020	$\frac{1}{26620200}$	27	7	43	5

163. What do the tables under this article contain ?

164. Proportional Magnitudes of the Planets represented to the Eye. The magnitudes of the primary planets proportional to each other, and to a supposed globe of 12 inches in diameter for the sun, are represented to the eye in the frontispiece to this work. Also, a delineation of the apparent magnitudes of the sun, as seen from the different planets. According to these proportional magnitudes of the planets, the distance of Mercury from a sun of 12 inches in diameter, would be 42 feet, Venus 78 feet, the Earth 108 feet, Mars 163 feet, the Asteroids 297 feet, Jupiter 558 feet, Saturn 1024 feet, Uranus 2059 feet, and Neptune 3221 feet. In accordance with this representation, the moon's distance from the earth would only be about $3\frac{1}{4}$ inches

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CHAPTER XVI.

COMETS.

165. Remarks. Comets are bodies which occasionally visit our system. The sun is the centre of their attraction. They appear in every part of the heavens, and move in all directions. Their orbits are so very eccentric, that when they are in those portions of them, which are farthest from the sun, they become invisible, and after traversing regions far beyond the orbit of the remotest planet, unseen for years, they make their ap-

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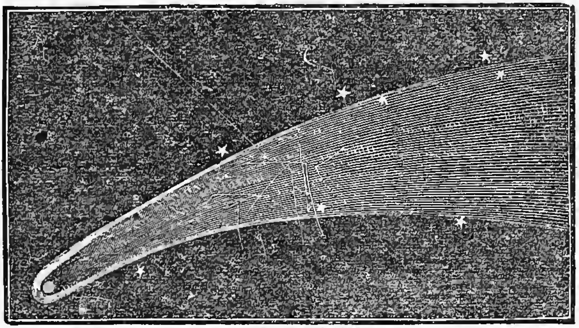
164. According to the proportional magnitude of the planets represented in the frontispiece, how large is the sun? What will be the distances of the several planets from this supposed sun? What the moon's distance from the earth?

165. What are comets? What is the centre of their attraction? In what part of the heavens do they appear, and in what directions do they move? What is said of the eccentricity of their orbits?

pearance again. Some, after visiting our system, pass off into boundless regions of space and never return.

The general opinion is, that they shine by reflecting the light of the sun. They are visible but for a short time, and only when near their perihelion. Many, on account of their dimness cannot be seen by the unassisted eye; others, on the contrary, are splendid in their appearances.

166. Parts of a Comet. Comets are composed of three principal parts, namely, the *nucleus*, the *head*, and *tail*. (See the drawing.) The most brilliant central and condensed part is called the *nucleus*, around which is a nebulous envelope to a considerable extent, called the *coma*, from its hairy appearance, (the word comet is derived from *coma*, hair,) which, with the nucleus, composes the *head* of the comet. The luminous train which pro-



Great Comet of 1811.

ceeds from the head, in a direction *opposite to the sun*, and expands sometimes to a great distance, is called the *tail* of the comet. Ordinarily, the tail is curved, having the concave side towards that part of the orbit from which the comet is just receding. The smaller comets, have frequently short tails, and some are entirely destitute of these appendages.

What of some after visiting our system? How do they shine? How long are they visible, and when? What is said of many, and others?

166. Of how many principal parts are comets composed? Name them? Describe the nucleus. What is the derivation of the word comet? Describe the coma. The head. The tail. What is said of small comets?

167. Orbits of Comets. Comets move in very eccentric orbits, as already noticed. The eccentricity of some of their orbits is so great, that that part which is near their perihelion, or which is described during the visibility of the comet, does not sensibly differ from a parobala, having the sun in the focus. If some comets, as is asserted, move in hyperbolas, they can never visit our system but once, and after having passed their perihelia, must either move off indefinitely, or advance in their way to another system, at an inconceivable distance.

The elements of a comet's orbit, are the same as those of a planet's orbit, but the computation of the former is much more difficult and laborious than that of the latter, since the periodic time and semi-axis major are unknown. Notwithstanding, the elements of the orbits of about 150 comets have been computed and registered, with a view to detect their future returns. When a comet appears, if the elements of its orbit agree or nearly agree with any set of elements in the catalogue, it is presumed that the same comet formerly noticed, has returned again. The orbits of comets are generally inclined under large angles with the ecliptic.

168. Physical constitution of Comets. As to the nature of these mysterious bodies, philosophers seem to know but little or nothing. Some suppose them to be wholly gaseous. On the other hand, it has been maintained that the nucleus at least, is solid and opaque Stars have been seen through the nebulosity, and some astronomers assert that they have seen them through the nucleus. The tail becomes more attenuated and enlarged, in proportion to its distance from the head of the comet.

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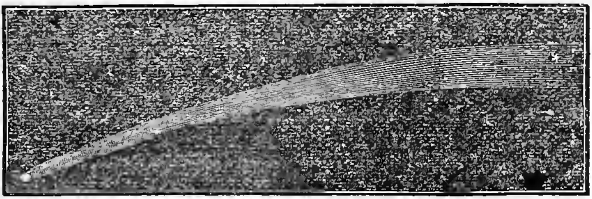
167. What is said of the orbits of some comets as to their great eccen tricity? What is said of those comets asserted to move in hyperbolas? Why is the computation of the elements of a comet's orbit more difficult than that of the elements of a planet's orbit? Of how many have the elements been computed? With what view are these elements registered?

168. What is known of the nature of comets? What have some supposed them to be? What has been maintained of the nucleus?

Comets have passed so near some of the planets, that had they been possessed of a density approaching that of any other heavenly body, they would have disturbed these planets, but not the slightest perturbations have been detected in them; hence, it is inferred that the quantity of matter in a comet must be very small.

169. Distances and Dimensions of Comets. We will here notice some particulars respecting two or three of the most remarkable comets. One of these was the great comet which appeared towards the close of the year 1680. At its perihelion, it was but 146,000 miles from the sun's surface, and at its aphelion, 13,000,000,000 miles from that luminary. Its period is supposed to be about 575 years. When nearest the sun, its velocity has



Great Comet of 1843.

been computed at 1,240,000 miles per hour! Its nucleus was calculated to be 10 times as large as the moon, and its tail when longest, 124,000,000 miles.

A comet very remarkable for its peculiar splendor, appeared in 1811. The diameter of the inner nucleus was 2600 miles, and that of the head, 132,000 miles. The greatest length of the tail was 132,000,000 miles. From the most accurate observations on its motion, its period is calculated at about 3000 years. Some astronomers compute it to exceed 4000 years.

We will mention one other, the great comet of 1843.

Have the planets been disturbed when comets passed near them What is the inference?

169. What were the perihelion and aphelion distances of the great comet of 1680? What its period? Its velocity when nearest the sun? How large was the nucleus? How long was the tail? Give the dimensions of the great comet of 1811. Its period.

(See the drawing.) This comet of which we are treating, was remarkable for its near approach to the sun. According to Professor Norton, of Delaware College, when at its perihelion, which was February 27th, 5 P. M., Phil. time, it was but 520,000 miles from the sun's centre, or less than 100,000 miles from his surface.

170. HALLEY'S COMET. The periodic times of but few comets have been determined. Dr. Edmund Halley, a celebrated English astronomer, having calculated the elements of the orbit of a comet, which appeared in the year 1682, found that it was identical with the comets of 1456, 1531, 1607, and therefore predicted its return in 1758. Thus giving to it a period of about 75½ years. Subsequently, Clairaut, an eminent French mathematician, having found from laborious and intricate calculations, that the attractions of Saturn and Jupiter would prolong its period, predicted that it would not reach its perihelion until the 13th of April, 1759. It appeared about the end of December, 1758, and arrived at the perihelion on the 13th of March following, but one month sooner than the time fixed by Clairaut. This comet came again to its perihelion on the 16th of November, 1835, but nine days after the time fixed by Pontécoulant, a distinguished French astronomer.

The motion of this comet in the orbit, which is inclined 18° to the ecliptic, is retrograde. Its perihelion distance is 57,000,000 miles, and aphelion distance, 3400,000,000 miles, nearly equal twice the distance of Uranus.

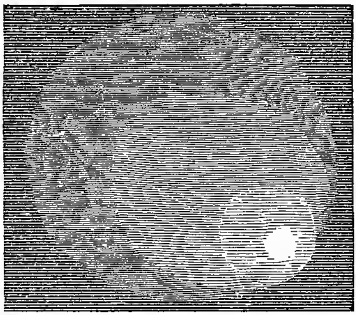
What was remarkable of the great comet of 1843? When did it come to its perihelion, and what was its distance then from the sun?

170. Who calculated the elements of the orbit of a comet which appeared in 1682? What did Dr. Halley find and predict? What is the period of this comet? What did Clairaut subsequently find and predict concerning it? How much sooner did it come to the perihelion, than the time fixed by Clairaut? When did this comet come again to its perihelion, and how long after the time fixed by Pontécoulant? What is said of its motion? What are the perihelion and aphelion distances?

it is called *Halley's Comet*, from the fact that Halley first ascertained the elements of its orbit, and correctly predicted the time of its return.

171. ENCKE'S COMET. A comet was discovered at Marseilles, on the 26th of November, 1818, by M. Pons, the elements of the orbit of which, and periodic return, were ascertained by Professor Encke, of Berlin; hence, it is called *Encke's Comet.* It was considered identical with the comets seen in 1786, 1795, and 1805. It is remarkable for the shortness of its periodic revolution, which it acoomplishes in 1207 days, or nearly $3\frac{1}{3}$ years, and hence, it is also called the *Comet of short period.* This comet has reappeared in 1822, 1825, &c., as predicted. It came again to its perihelion near the close of the year 1848. The inclination of its orbit to the ecliptic is $13\frac{1}{3}°$, the perihelion is about the distance of Mercury from the sun, and the aphelion that of Jupiter.

Encke's comet is small and has no tail; (see the drawing) it s of feeble light, and invisible to the naked eye, except in favorable circumstances. There is a singular peculiarity attending this comet, namely, that its period is continually shortening, and its mean distance from the sun gradually lessening. Professor Encke accounts for it by a resistance offered to the motion of the comet, arising from



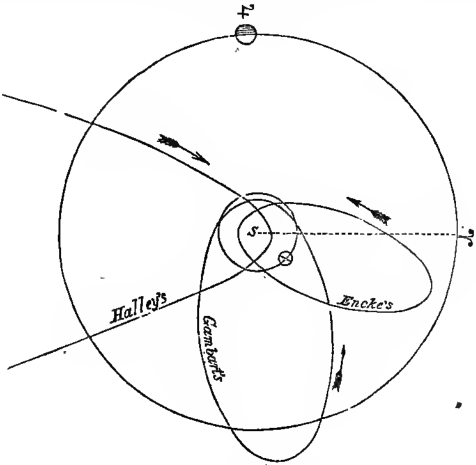
Why called Halley's comet?

171. When and by whom was Encke's comet discovered, and why so called? With the comets seen in what years was it considered identical? For what is it remarkable? What is its period, and what also called? When did it last come to its perihelion? What is the inclination of its orbit? What are the perihelion and aphelion distances? Can it be seen by the naked eye? What singular peculiarity attends this comet? How does Professor Encke account for this?

a very rare etherial medium in space. Sir John Herschel has advanced the opinion that, "it will probably fall ultimately into the sun, should it not first be dissipated altogether, a thing no way improbable."

172. GAMBART'S COMET. This comet was discovered by M. Biela, at Josephstadt, in Bohemia, on the 27th of February, 1826, and ten days afterwards, by M. Gambart, at Marseilles. Gambart calculated its parabolic elements, and found from the catalogue of comets, that it had been seen in 1789 and 1795. The periodic time is 2460 days, or 6¾ years. According to this prediction, it appeared in the latter part of 1832, but not in 1839, owing to the unfavorable situation of the earth. It was seen at its last return in the beginning of 1846. It is called *Gambart's Comet,* sometimes, *Biela's Comet.*

The inclination of the orbit of this comet, is 13°, the perihelion is just within the earth's orbit, and aphelion beyond Jupi-



What opinion has Sir John Herschel advanced on this subject?

172. When, and by whom was Gambart's comet discovered? Who calculated its parabolic elements? What is its period? When was it last seen?

ter's orbit. It is small, without either tail, or any appearance of a nucleus, and is not discernible without a telescope.

The preceding figure represents the orbits of the three comets, whose periodic times have been accurately determined. S, represents the sun, the small circle, the orbit of the earth, and the large circle that of Jupiter.

173. Number of Comets. The number of comets which have been observed at different times since the Christian era, is probably seven or eight hundred; and although many of them may have been reappearances of the same comet, yet when we consider, that, before the invention of the telescope, none but the largest and most conspicuous had been noticed, the actual number may be some thousands. Nevertheless, owing to the long periods of many of them, and the comparatively short time which they are observable, the orbits and periods of but *three* are known with certainty. Besides these three, which we have described in the preceding articles, there are some others, which are supposed to be identical with former comets, but which have not yet returned to verify the predictions concerning them.

CHAPTER XVII.

FIXED STARS.

174. Remarks. Having treated of those heavenly bodies belonging to the solar system (35), and having given their positions, connexions, periods, distances, mag-

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What are the perihelion and aphelion distances? Of what is it destitute?

173. What is the number of comets probably observed since the Christian era? What may be the actual number? Why are the orbits and periods of but three known with certainty? What is supposed of some others?

174. What orbs do we now come to notice?

nitudes, and phenomena, derived from the most accurate observations of modern times, we now come to notice those orbs which lie at a distance far beyond this system. These are the *Fixed Stars*, so called, because they are known to keep nearly in the same position, and at the same apparent distances from each other. They have an apparent motion from east to west, in common with the other heavenly bodies, caused by the diurnal motion of the earth on its axis from west to east.

A fixed star twinkles, and thereby may be distinguished from a planet which does not. Various hypotheses have been given explanatory of the cause of this phenomenon, which is now generally acknowledged as a consequence of the unequal refraction of light, produced by inequalities and undulations in the atmosphere.

175. NUMBER OF STARS AND THEIR CLASSIFICATION. The number of fixed stars which are visible to the naked eye, in both hemispheres, is about 4000. Of this number, not quite 2000 can be counted above the horizon at any given place. Besides these discernible by the unaided eye, the telescope brings into view innumerable multitudes of others, and every increase of its power greatly increases the number. These are, therefore, called *Tel escopic Stars.*

The stars, on account of their various degrees of brightness, and apparently various magnitudes, are divided into classes. Those which appear the largest, are called stars of the *first magnitude ;* the next to these in appearance, stars of the *second magnitude ;* and so on to the *sixth magnitude,* which are the smallest that can be

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What called, and why ? How may a fixed star be distinguished from a planet ? What is the generally acknowledged cause of this phenomenon, or twinkling of the fixed stars ?

175. What is the number of stars visible to the naked eye in both hemispheres ? How many may be counted above the horizon at any given place ? What are telescopic stars ? How are the stars, on account of their various degrees of brightness, and apparently various magnitudes, divided ? Describe the different classes or magnitudes ?

seen by the naked eye. But few eyes can distinguish those belonging to this magnitude, even in the clearest night. The classification is continued under the power of the telescope, down to the 16th magnitude. There are about 17 stars of the first magnitude, 76 of the second, 223 of the third, and so on, the numbers of each class increasing very rapidly to the sixth magnitude.

176. ARRANGEMENT OF THE STARS INTO CONSTELLATIONS. The ancients divided the heavens into three principal regions. 1st, the zodiac, 2d, all that part of the heavens on the north side of the zodiac, and 3d, all that part on the south side of it. These, in order to distinguish the stars from one another, they again sub-divided into groups of stars, or *Constellations.* According to their superstitious notions, these constellations were conceived to represent the outlines of certain animals, imaginary beings, or figures, and thus were named accordingly. This, no doubt, was done for the sake of convenience, that a person may be directed to any part of the heavens where a particular star is situated.

It is desirable that a more scientific and definite division of the celestial sphere could be arranged, than the present unnatural and mythological division into figures, "like to corruptible man, and to birds, and four-footed beasts, and creeping things."

The zodiacal constellations are 12, the northern 34, and the southern 47, making in all 93. Of these, 48, including those of the zodiac, were formed in ancient times, the rest within the last two or three centuries.

Which are the smallest that can be seen by the naked eye? How far is the classification continued under the power of the telescope? How many stars of the first, second, &c., magnitudes?

176. How did the ancients divide the heavens? Name them. How did they again sub-divide these? What did they conceive these constellations to represent? Why was this done? How many zodiacal constellations? Northern? Southern? How many in all? Of these, how many were formed in ancient times? When the rest?

The following tables contain all the constellations, with the number of stars in each, and the names of some of the principal.

I.—ZODIACAL CONSTELLATIONS.

Names of the Constellations.	No. stars	Names of the principal Stars and their magnitudes.
1. Aries, the Ram, - -	66	Arietis, 2. [Hyades.
2. Taurus, the Bull,	141	Aldebaran, 1; Pleiades,
3. Gemini, the Twins, - -	85	Castor, 1; Pollux, 1.
4. Cancer, the Crab, -	83	Acubens, 3.
5. Leo, the Lion, - -	95	Regulus, 1; Denebola, 2
6. Virgo, the Virgin, -	110	Spica Virginis, 1.
7. Libra, the Balance, -	51	Zubeneschamale, 2.
8. Scorpio, the Scorpion, -	44	Antares, 1.
9. Sagittarius, the Archer, -	69	Alrami, 3.
10. Capricornus, the Goat, -	51	Dschabe, 3.
11. Aquarius, the Water-bearer,	108	Scheat, 3.
12. Pisces, the Fishes, -	113	

II.—NORTHERN CONSTELLATIONS.

Names of the Constellations.	No. stars	Names of the principal Stars and their magnitudes.
1. Ursa Minor, the Little Bear,	24	Pole Star, 2.
2. Ursa Major, the Great Bear,	87	Dubhe, 1; Alioth, 2.
3. Cor Caroli, Charles' Heart,	3	
4. Draco, the Dragon,	80	Rastaben, 2.
5. Cepheus, Cepheus, [Chair,	35	Alderamin, 3.
6. Cassiopeia, the Lady in her	55	Schedir, 3.
7. Camelopardalis, the Camelopard, -	58	
8. Cygnus, the Swan, -	81	Arided, 2.
9. Lynx, the Lynx, -	44	
10. Lacerta, the Lizard, -	16	
11. Auriga, the Wagoner, -	66	Capella, 1.
12. { Perseus et Caput Medusæ, Perseus & the head of Medusa	59	Algenib, 2; Algol, 2

Name the zodiacal constellations. In what constellation are the Pleiades, NORTHERN CONSTELLATIONS,—*Continued.*

Names of the Constellations.	No. stars	Names of the principal Stars and their magnitudes.
13. Musca, the Fly,	6	
14. Triangula, the Triangles,	16	
15. Andromeda, Andromeda,	66	Mirach, 2; Alamak, 2.
16. Lyra, the Harp, -	21	Vega, or Lyra, 1.
17. Hercules, Hercules, -	113	Ras Algethi, 3.
18. Corona Borealis, the Northern Crown, -	21	Alphecca, 2.
19. Boötes, the Herdsman, -	54	Arcturus, 1; Mirach, 3.
20. Canes Venatice, the Greyhounds, - -	25	
21. Coma Berenices, Berenice's hair, - - -	43	
22. Leo Minor, the Little Lion,	53	
23. Mons Mænalus, the Mountain Mænalus,	11	
24. Serpens, the Serpent, -	64	Unuk, 3.
25. Serpentarius, the Serpent-bearer - -	74	Ras Alhague, 2.
26. Taurus Poniatowski, the Bull of Poniatowski,	7	
27. Scutum Sobieski, the Shield of Sobieski,	8	
28. Aquila, the Eagle, } 29. Antinoüs, Antinoüs, }	71	Altair, 1.
30. Delphinus, the Dolphin,	18	Svalorin, 3.
31. Sagitta, the Arrow,	18	
32. Vulpecula et Anser, the Fox and Goose, -	35	
33. Equüleus, the Little Horse,	10	
34. Pegasus, the Flying Horse,	89	Markab, 2; Scheat, 2.

What are the names of the principal stars in these? Those of the first magnitude? Second? Third? Repeat the northern constellations. Give the names of the principal stars in these. Repeat those of the first magnitude, second, and third.

III.—SOUTHERN CONSTELLATIONS.

Names of the Constellations.	No. stars	Names of the principal Stars and their magnitudes.
1. Cetus, the Whale, -	97	Menkar, 2; Mira, 2.
2. Eridanus, the River Po,	84	Achernar, 1.
3. Brandenburgium Sceptrum, the Sceptre of Brandenburgh,	3	
4. Lepus, the Hare, - -	19	
5. Orion, Orion, - -	78	Rigel, 1; Betelguese, 1.
6. Canis Major, the Great Dog,	31	Sirius, 1.
7. Monoceros, the Unicorn,	31	
8. Canis Minor, the Little Dog,	14	Procyon, 1.
9. Hydra, the Water Serpent,	60	Cor Hydra, 1.
10. Sextans, the Sextant, -	41	
11. Crater, the Cup, -	31	Alkes, 3.
12. Corvus, the Crow, -	9	Algorab, 3.
13. Pyxis Nautica, the Mariner's Compass, - - -	8	
14. Machina Pneumatica, the Air Pump, - - -	24	
15. Crux, the Cross, - -	6	
16. Centaurus, the Centaur,	35	
17. Lupus, the Wolf, - -	24	
18. Norma, the Rule, - -	12	
19. Circinus, the Compasses,	7	
20. Triangulum Australe, the Southern Triangle, -	5	
21. Ara, the Altar, - -	9	
22. Telescopium, the Telescope,	9	
23. Corona Australis, the Southern Crown,	12	
24. Pavo, the Peacock,	14	
25. Indus, the Indian, -	12	
26. Microscopium, the Microscope	10	
27. Piscis Australis, the Southern Fish,	24	Fomalhaut, 1.
28. Grus, the Crane,	13	
29. Toucan, the American Goose,	9	

Repeat the southern constellations. Name the principal stars in them.

SOUTHERN CONSTELLATIONS,—*Continued.*

Names of Constellations.	No. stars	Names of the principal Stars and their magnitudes.
30. Phœnix, the Phœnix, -	13	
31. Apparatus Sculptoris, the Sculptor's Apparatus,	12	
32. Fornax Chemica, the Furnace	14	
33. Horologium, the Clock, -	12	
34. Cæla Sculptoria, the Engraving Tools,	16	
35. Columba Noachi, Noah's Dove	10	
36. Equuleus Pictoris, the Painter's Easel, -	8	
37. Dorado, or Xiphias, the Sword Fish,	6	
38. Piscis Volans, the Flying Fish	8	
39. Argo Navis, the Ship Argo,	64	Canopas, 1 ; Naos, 2.
40. Robur Caroli, Charles' Oak,	12	
41. Chamæleon, the Chameleon,	10	
42. Musca Australis vel Apis, the Southern Fly, or Bee, -	4	
43. Apus vel Avis Indica, the Bird of Paradise,	11	
44. Octans Hadleianus, Hadley's Octant, - - -	43	
45. Hydrus, the Water Snake,	10	
46. Reticulum Rhomboidum, the Rhomboidal Net,	10	
47. Mons Mensiformis, the Table Mountain,	10	

177. BAYER'S CHARACTERS. The stars in each constellation are denoted by the letters of the Greek and Roman alphabets; by placing the first Greek letter α to the principal star, β to the second in magnitude, γ to the third, and so on till the Greek alphabet is finished; then begining with the Roman letters, *a*, *b*, *c*, &c. Thus, *a*

177. How are the stars in each constellation denoted? Explain this method of denoting the stars?

Lyræ is the brightest star in the constellation Lyra, β Lyræ, the next in brightness to α, &c. Some of the brightest stars have particular names; thus, Regulus or α Leonis, Aldebaran or α Tauri, &c. This useful method of denoting the stars, was first introduced by John Bayer, of Augsburg, in Swabia, about the year 1603. When any constellation contains more stars than can be marked by the two alphabets, the numbers 1, 2, 3, &c., are used in succession.

We here insert the Greek alphabet for the use of those who may be unacquainted with it.

Greek Characters.	Names.	Roman Characters.	Greek Characters.	Names.	Roman Characters
α,	Alpha,	a,	ν,	Nu,	n,
β ϐ,	Beta,	b,	ξ,	Xi,	x,
γ Γ,	Gamma,	g,	ο,	Omicron,	ŏ,
δ,	Delta,	d,	π,	Pi,	p,
ε,	Epsilon,	ĕ,	ρ,	Rho,	r,
ζ,	Zeta,	z,	σ ς,	Sigma,	s,
η,	Eta,	ē,	τ,	Tau,	t,
ϑ θ,	Theta,	th,	υ,	Upsilon,	u,
ι,	Iota,	i,	φ,	Phi,	ph,
κ,	Kappa,	k,	χ,	Chi,	ch,
λ,	Lamda,	l,	ψ,	Psi,	ps,
μ,	Mu,	m,	ω,	Omega,	ō,

178. The Milky Way.—Nebulæ. That bright luminous zone in the heavens, visible to every observer, is called the *Galaxy*, but more frequently the *Via Lactea*, or *Milky Way*, from its resemblance to the whiteness of milk. This band encircles the whole sphere of the heavens, and cuts the ecliptic nearly in the solstitial points at an inclination of about 60°. It varies in breadth from

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By whom was this useful method first introduced? When are the numbers 1, 2, 3, &c. used?

178. Describe the galaxy or milky way. What does it encircle, and ..w does it cut the ecliptic? Does it vary in breath and brightness?

about 5° to 15°, and also in brightness, being more luminous in some parts than others. Its whiteness, so perceptible in a clear night, is caused by the joint light of the vast number of small stars in close proximity, of which it is composed. The Milky Way when examined by powerful telescopes, is found, according to Sir John Herschel, "to consist entirely of stars scattered by millions."

Besides the Milky Way, which may be considered as a nebulous belt, there are various spots, resembling white clouds, seen in the starry heavens by the telescope. These are properly called *Nebulæ,* and are arranged into two classes, *resolvable* and *irresolvable.* The resolvable nebulæ have been separated into stars by means of the telescope, but the irresolvable have not, though submitted to the space-penetrating power of the largest telescopes yet constructed.

From recent observations made by Lord Rosse's telescope of 6 feet reflector, and 54 feet focus, some nebulæ hitherto considered irresolvable, have been separated into clusters of stars. It is expected that new discoveries will be made by this wonderful instrument, not only in the nebulæ, but in every other heavenly body the subject of observation.

179. Groups and Clusters of Stars. Every attentive observer of the heavens, in a clear night, will perceive that the stars are irregularly distributed in the concave firmament. In some places, they appear collected together into *groups,* while in others, they are more scattered and indiscriminately arranged.

Of these groups the most conspicuous and beautiful is that called *Pleiades,* which, within its small compass, ex-

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By what is its whiteness caused? Of what does it consist according to Sir John Herschel? What are nebulæ? How arranged? Describe each class. What is said of recent observations made by Lord Rosse's telescope?

179. What will every attentive observer of the heavens perceive? How do they appear in some places? Which is the most conspicuous and beautiful group?

hibits through a telescope of moderate power 50 or 60 distinct stars. This group is in the constellation Taurus, and to the unassisted eye, consists of six or seven stars close together, and nearly at the same apparent distance from each other. The constellation *Coma Berenices* situated north of Virgo, is another group, more diffused than the Pleiades, and to the naked eye composed of larger stars. In the constellation Cancer, there is a group called *Præsepe*, or the Bee-hive, of a nebulous appearance, which the telescope easily resolves into small distinct stars. Another spot is found in the sword-handle of Perseus, which exhibits, through a telescope of great power, a group of stars smaller in size than those composing the other groups already noticed.

Besides groups of stars, there are found in the nocturnal heavens, many *clusters*, which differ from groups in their elliptical or round figures, and in the crowded and condensed appearance of the stars composing them, especially towards the centre. None but telescopes of great power will show them to consist of separate and distinct stars.

180. Variable and Temporary Stars. Some stars are subject to periodical changes in their brightness, and are therefore called *Variable Stars*. The star *o* Ceti was discovered about the close of the 16th century to be of this kind. From the time of its greatest brightness, being then a star of the second magnitude, it decreases during three months, when it becomes invisible; after the lapse of five months, it reappears, and in about three months is again restored to its former brightness. The period of this star is therefore eleven months. A variable star has been noticed in the constellation Hydra, and another in the Swan. There are many stars known to

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Where is the group Pleiades? Describe it. Describe the group Coma Berenices. The group Præsepe. Where is there another group? How do clusters differ from groups?

180. What are variable stars? What is said of the star *o* Ceti? What is its period? What others have been noticed?

vary in lustre, without becoming entirely invisible. The most remarkable of these is *Algol* or α Persei, which retains its magnitude for 2*d.* 12*h.*, and then in 4 hours diminishes to a star of the fourth magnitude, when it begins to increase, and in the succeeding 4 hours regains its original brightness, performing its period in about 2 days 20 hours.

Several instances are on record, of new stars having appeared where none had been before observed. These are called *Temporary Stars.* The most ancient is that given by Hipparchus, who flourished about 120 years before the Christian era. In 945, a new star appeared, and another in 1264; but the most remarkable was that observed by Tycho Brahe, in November, 1572. This star appeared suddenly in Cassiopeia, and shone with a brilliancy equal to that of Sirius. In three weeks after its first appearance, it commenced to diminish in brightness, and in 16 months entirely disappeared, not having since been seen.

181. DOUBLE AND BINARY STARS. When certain stars, which to the naked eye, and even when assisted by a telescope of moderate power, appear single, are examined by telescopes of considerable power, they are resolved into two, sometimes three or more stars. These are called *Double*, or *Multiple Stars.* Previous to the time of the elder Herschel, but few stars were known to be double, but by the exertions of this great astronomer, and others of distinction, several hundred are now ascertained to be of this kind. Some of these, no doubt, may appear double from the circumstance, that the two stars, though far remote from, and unconnected with each other, appear nearly in the same visual line. The stars

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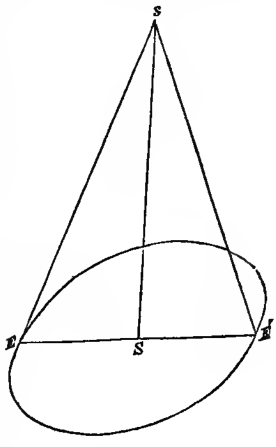
Describe the changes in the star Algol. What are temporary stars When did new stars appear? Describe the one observed by Tycho Brahe.

181. What are double or multiple stars? Are there many now ascertained to be of this kind? From what circumstance may some of them appear double?

composing a double star are generally of unequal magnitude, and exhibit the singular phenomenon of shining with differently colored light.

A most important and interesting discovery has been made by Sir W. Herschel, in relation to many of the double stars, namely, that they are physically connected by the laws of gravitation, and revolve round each other, or rather round their common centre of gravity. These, therefore, are called *Binary Stars*, sometimes *Binary Systems*. The following are some of the most prominent binary stars with their periods: η Coronæ, 43 years; ζ Cancri, 55 years; ξ Ursæ Majoris, 58 years; ω Leonis, 83 years; γ Virginis, 145 years; Castor, or α Geminorum, 232 years; 61 Cygni, 540 years; and σ Coronæ, 608 years.

182. Annual Parallax and Distances of the Stars. When two straight lines are conceived to be drawn from a star, the one to the sun and the other to the extremity of the radius vector of the earth's orbit, at right angles to the first line, the angle contained by these lines is called the *Annual Parallax* of that star. Or the annual parallax is the greatest angle at the star subtended by the radius of the earth's orbit.



Thus let the line *s* S be drawn from *s* the star to S the sun, and another line drawn to E the extremity of the radius vector S E at right angles to the first line *s* S; then the angle S *s* E will be the annual parallax of the star *s*. Pro-

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What singular phenomenon do they generally exhibit? What interesting discovery has been made by Sir W. Herschel in relation to many of the double stars? What are these called? Name some of the most prominent binary stars and their periods?

182. What is the annual parallax of a star? Illustrate the annual

duce E S to E′ and join E′ *s*; now it is evident if the angle E *s* E′, which is double the parallax, be sensible, it could be determined by finding the difference in position of the star *s*, as viewed from E and E′, two opposite points of the earth's orbit.

Hence the most eminent astronomers have, at opposite seasons of the year, determined within the nearest degree possible, the right ascensions and declinations (16) of some stars, which from their brilliancy and apparent magnitudes, were thought to be nearer the earth than the generality of others, with the view of finding their annual parallax. But the result of their observations has led them to conclude that the angle in question is so small as not to be detected by this method, subject to small errors arising from the imperfections of the best instruments, and from the corrections for refraction, aberration and nutation.

However, Professor Bessel, of Konigsberg, appears to have been successful in determining the parallax of the binary star 61 Cygni. This star, on account of its great proper motion, (63), which amounts to 5″.3 in a year, and its large apparent orbit of 16″, is thought to be nearer the earth than any other. Hence Bessel conceived the grand idea of finding the difference between the parallaxes of the middle point of the line joining the components of this star, and a small stationary star seen in nearly the same direction, and therefore supposed to be at a much greater distance. This difference in the parallaxes will nearly equal the absolute parallax of the star 61 Cygni. The method of obtaining this was by finding the semi-annual changes in the distance between the stars, and thereby having avoided the inevitable small errors in the corrections for refraction, aberration, &c., necessarily attending the method by finding the right ascensions and declinations. Bessel, for the sake of greater exactness, used two small stars, and taking the middle point between the two stars composing the double star, 61 Cygni, for the situation of the star, found its annual parallax to be 0″.3483.

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parallax by the diagram. What have the most eminent astronomers done, with the view of finding the annual parallax of some stars? What has the result of their observations led them to conclude? Why cannot the angle in question be detected by this method? Who appears to have been successful in determining the parallax of the star 61 Cygni? Why is this star thought to be nearer the earth than any other? What grand

Knowing the parallax, we have in the right angled triangle E S *s*, sin E *s* S : Radius : : E S : E *s*; taking E S, the distance of the sun from the earth, equal to unity, and the length of radius expressed in seconds, (57),

$$E\,s = \frac{\text{Radius}}{\sin E\,s\,S} = \frac{206264''}{0''.3483} = 592200,$$

which shows how many times the star 61 Cygni is farther from the earth than the sun. And 95000000*m.* $\times$ 592200 = 56259-000000000 miles the distance of this star from the earth.

The velocity of light is 192961 miles per second of time (142), and 192961*m.* : 56259000000000*m.* : : 1*s.* : 291556324*s.* = 9 years 87 days. So that if the star 61 Cygni were now just launched into existence by the Almighty Creator, 9¼ years, nearly, must elapse before its light would reach this our distant globe.

183. The Longitude of a Ship at Sea determined by the Moon's distance from some of the principal Stars in or near her Orbit. When at the same instant the hours of the day at two places are determined, the longitude of the one from the other is easily obtained. The method of finding the longitude of a place by means of the eclipses of Jupiter's satellites, has already been given, (141), but it cannot be accurately employed at sea on account of the motions of the vessel. Chronometers, which are well-regulated time pieces, are now extensively used at sea for this purpose. The difference between the mean time at the ship, and that of a chronometer which can be depended upon, and which shows the mean time at the first meridian (9), converted into degrees at the rate of 15° to an hour, will give the longitude. If the time at the ship be later than that shown by the chronometer, the

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idea did Bessel conceive? Explain his method. When the parallax is known, how is the distance found? What is the distance of this star from the earth? What time is required for the transmission of its light to our globe?

183. What is the subject of this article? Why cannot this be done by means of the eclipses of Jupiter's satellites? What are chronometers? Explain the method of finding the longitude of a ship at sea by means of a chronometer. Can chronometers be depended upon?

longitude is *east* of the first meridian, but if earlier, it is *west*. However, as the best chronometers are subject to variations from change of temperature and other causes, it becomes important to the mariner to be possessed of a method not dependent on the motions produced by human mechanism, but on the sure and well established motions of the heavenly bodies. This latter method, which depends on the moon's distance from any heavenly body in or near her path, and therefore called the *Lunar Method*, we will now briefly explain.

In the Nautical Almanac, the moon's true angular distances from the sun, Venus, Mars, Jupiter, Saturn and nine principal stars in or near her path, namely, α Arietis, Aldebaran, Castor, Pollux, Regulus, Spica Virginis, Antares, Altair and Fomalhaut, are given for every three hours, apparent Greenwich time, of every day in the year. The time for any intermediate distance may easily be found by proportion sufficiently correct. These distances in the Almanac, are the distances between the centres of the bodies, calculated as if observed from the earth's centre; the observed distance at the ship must therefore be reduced to this true distance. This reduction, which consists in corrections for parallax, refraction and semi-diameters, constitutes the chief difficulties of the problem. All the treatises on Navigation give formulas for this reduction. When the true angular distance of the moon at the ship has been found, and also the time at Greenwich found, when she has the same true angular distance; the difference between this time, and that when the observation was made reduced to degrees, will give the longitude.

What then becomes important to the mariner? On what does this method depend, and what therefore called? What are given in the Nautical Almanac? Name the principal stars from which the moon's distances are given. For what time are these distances computed? From what point as if observed are they calculated? What constitutes the chief difficulties of the problem? When this reduction is made, how is the longitude found?

CHAPTER XVIII.

OBLIQUITY OF THE ECLIPTIC, EQUINOCTIAL POINTS, PRECESSION OF THE EQUINOXES, NUTATION, AND ABERRATION OF LIGHT.

184. OBLIQUITY OF THE ECLIPTIC. The inclination of the planes of the ecliptic and equinoctial, is the obliquity of the ecliptic (10). By taking half the difference between the sun's greatest and least meridian altitudes at any place, the obliquity of the ecliptic, or the sun's greatest declination, will be obtained. Or the difference between the meridian altitude of the sun, found at the time of the summer or winter solstice, and the height of the equinoctial above the horizon, which is equal to the complement of the latitude of the place, will give the obliquity.

According to the most accurate observations of modern times, made at considerable intervals, the obliquity of the ecliptic is continually diminishing. This diminution is very small, and at the mean of about 51″ in a century, called the secular diminution. It is the result of the action of the planets, particularly Venus and Jupiter, upon the earth. After the lapse of a very long period, according to La Place and others, the obliquity will begin to increase, the limit of variation being about 2° 42′. The present obliquity of the ecliptic, 1848, is 23° 27′ 23″.

185. EQUINOCTIAL POINTS. The equinoctial points may be determined by observing the sun's declination at noon for a few days before and after the equinoxes. Then on two consecutive days of these, it will be found that his declination will have changed from north to

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184. Define the obliquity of the ecliptic. How is it obtained? Is the obliquity diminishing? What is its amount in a century? Of what is it the result? What is said of it after the lapse of a very long period? What is the present obliquity?

185. How may the equinoctial points be determined?

south, or from south to north; and hence the time when he crossed the equinoctial line can easily be found.

Thus, on the 19th of March, 1848, the sun's declination at apparent noon, Greenwich, was 22′ 52″ south, and on the following day at noon 49″ north; then 22′ 52″ + 49″ : 49 :: 24*h.* : 49*m.* 39*s.*; hence his declination was 0 on the 20th of March at 11*h.* 10*m.* 21*s.* A. M. apparent Greenwich time. Having found the precise instant when the declination is 0, and knowing the rate of the sun's apparent motion in the ecliptic, the point where the equinoctial and ecliptic intersect is easily ascertained. When one of these points is known, the other becomes known also, because they are directly opposite, or 180° distant. It is important that the equinoctial points should be accurately determined, because the natural or true year is computed from the instant on which the sun enters the vernal equinox until he returns to the same again.

186. Precession of the Equinoxes. The celebrated and ancient astronomer Hipparchus, from observations which he made at Alexandria about the year 130 before Christ, found that the autumnal equinox was about 6° east of the star Spica Virginis. He also, by much research, discovered the records of some observations made 150 years before, from which it appeared that the autumnal equinox was 8° east of the same star. Hence he concluded that the equinoctial points are not fixed in the heavens, but have a slow motion from east to west, or contrary to the order of the signs, which he called the *Precession of the Equinoxes*, because the time of the sun's return to one of these points, precedes that determined by the usual calculation. This motion, according to Hipparchus, is about 1° in 75 years.

Subsequent observations have confirmed the truth of this

Give the example illustrating this subject. How is the point where the equinoctial and ecliptic intersect, then ascertained? Why is it important that the equinoctial points should be accurately determined?

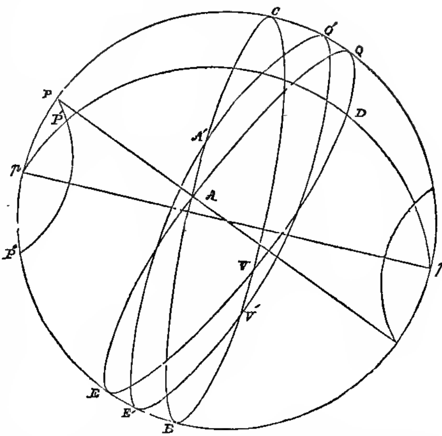
186. What did the ancient astronomer Hipparchus find? What did he also discover? What did he conclude from these facts? What did he call this motion of the equinoctial points, and why?

motion of the equinoctial points. In the year 1750, the autumnal equinox was observed to be 20° 21′ westward of Spica Virginis; hence 130*y.* + 1750*y.* : 1*y.* : : 6° + 20° 21′ : 50″.4, the annual precession. According to a series of accurate observations made by M. de la Caille, the precession is 50″.2 in a year. Hence if the sun crosses the equinoctial in a certain point this year, he will cross it 50″.2 to the west of the same point next year; and since the sun's daily motion in longitude is 59′ 8″ (96.) it follows that 59′ 8″ : 50″.2 : : 24*h.* : 20*m.* 23*s.* nearly, which shows how much the solar or tropical year is shorter than the siderial year (27.) The equinoctial points must have receded one sign in about 2150 years, and as the signs of the zodiac are reckoned from the point where the sun passes from the south to the north of the equinoctial, it follows that the longitudes of the stars since the infancy of astronomy, have increased about one sign; and hence the constellation Aries is now in Taurus, and Taurus in Gemini, &c. This may be seen by examining the celestial globe.

187. Retrograde Motion of the Pole of the Equinoctial, in a small Circle, round the Pole of the Ecliptic. Since the latitudes of the fixed stars are their distances from the ecliptic (18), and since these latitudes have been found, by observations made at different periods of time, to continue nearly the same, it follows that the position of the ecliptic must remain fixed or nearly so, with respect to the stars. Hence it is evident, that the precession of the equinoxes is the consequence of a slow motion of the equinoctial in the same direction: and because the equinoctial changes, its pole must also necessarily change.

What was observed in the year 1750? What is the amount of the precession in a year, according to M. de la Caille? From this, determine how much the solar year is shorter than the siderial year. How long does it require the equinoctial points to recede one sign? What is said of the longitudes of the stars, since the infancy of astronomy?

187. How is it known that the position of the ecliptic must remain fixed or nearly so, with respect to the stars? Of what therefore is the precession a consequence?



Let A B V C represent the ecliptic, and p its pole, which is stationary; also let A E V Q represent the equinoctial, and P its pole. Because the distance between the poles of two great circles is equal to their inclination, and because the obliquity of the ecliptic, (10), or the inclination of the equinoctial to the ecliptic, remains very nearly the same, the pole P must always be in the small circle P P′ P″ described about the pole p, at a distance from it equal to the obliquity of the ecliptic. When the equinoctial is in the position A E V Q, V, the vernal equinox, will be 90° distant from the poles P and p, and consequently will be the pole of the great circle P C p' E; hence this latter circle will be the position of the solstitial colure (9) at that time. Also, when the equinoctial is in the position A′ E′ V′ Q′ at any subsequent time, V′, the vernal equinox, will still be the pole of the solstitial colure, which must now assume the position p P′ D p', consequently P′, its intersection with the small circle P P′ P″, will be the pole of the equinoctial. Hence while the vernal equinox has retrograded from V to V′, the pole of the equinoctial, with an equal angular motion, has also retrograded from P to P′ in the small circle P P′ P″. The south pole of the equinoctial will evidently have a corresponding motion round the south pole of the ecliptic.

Since the precession of the equinoxes is 50″.2 in a year, we have 50″.2 : 360° : : 1y : 25816 years, the time required for the equinox and pole to make an entire revolution, which num-

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Draw the diagram and show that the pole of the equinoctial moves in a small circle round the pole of the ecliptic. Calculate the time required for the pole of the equinoctial to make an entire revolution.

ber of years completes the *Grand Celestial Period.* That star to which the north pole of the heavens, in its motion, comes nearest, takes then the rank of the pole star. In 1550 A. M. α Draconis was the pole star. The precession of the equinoxes will cause a small annual variation in the right ascensions and declinations (16) of the stars.

188. Physical Cause of the Precession of the Equinoxes. If we suppose the earth to have been originally in a fluid state, and rotating on its axis with its present velocity, it is plain that the particles of matter about the equatorial regions, on account of their greater distance from the axis, would have a greater centrifugal force than those near the poles; hence the parts about the equator would diminish in weight, and in order that the whole mass of the earth may be *in equilibrio*, its equatorial diameter will increase, and, accordingly, its axis will decrease, causing it to assume the figure of an oblate spheroid.

It has been proved by investigations in physical astronomy, that the precession of the equinoxes depends on the action of the sun and moon, on that protuberant matter around the equatorial parts, bringing the equator sooner under them, in each revolution, than if the earth were a perfect sphere. Hence the effects of this action of the sun and moon will occasion a small deviation of the earth's axis from its parallelism, and consequently a corresponding deviation in the position of the equinoctial and its pole, with respect to the fixed stars. The annual effects of these two bodies are respectively 15″ and 35″.2, that of the moon being greater, in consequence of her proximity to the earth. As there is no sensible change

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What is this period called? What star takes the rank of the pole star? When was a Draconis the pole star?

188. Supposing the earth originally in a fluid state, explain, particularly, the cause of its assuming the figure of an oblate spheroid. On what does the precession of the equinoxes depend? What will the effects of the action of the sun and moon occasion? What will be the consequence of this? What are the respective annual effects of the sun and moon?

in the latitudes of places, it follows that there is no sensible change in the terrestrial axis with respect to the matter of the earth.

189. NUTATION. It has been stated that the precession of the equinoxes is caused by the attractive force of the sun and moon on the protuberance of the equatorial regions of the earth. Now, when either of these bodies is in the plane of the equator, its attractive force will draw the earth towards it without changing the position of the axis, it keeping still parallel to itself; but the farther the body recedes from this plane, the more will the equatorial parts be drawn than the rest of the earth. Hence the sun and moon, on account of their various and continually changing positions with regard to the plane of the equator, will cause a small tremulous or oscillatory motion of the axis, called *Nutation.* The nutation was discovered by Dr. Bradley.

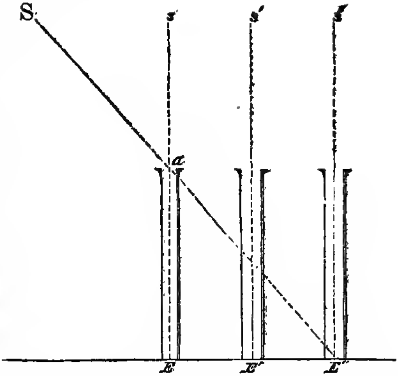
190. ABERRATION OF LIGHT. Dr. Bradley, towards the middle of the last century, made a series of careful observations with the view of finding the annual parallax of the fixed stars. But the result, instead of indicating a parallax, was the contrary to what had been expected. From this incident he discovered the fact that there is a small apparent change in the positions of the heavenly bodies, caused by the progressive motion of light, and the orbitual motion of the earth. This apparent motion, which is common to all the heavenly bodies, but more striking in the case of the fixed stars, is called the *Aberration of Light,* or simply *Aberration.* The theory may be thus explained.

Suppose E E″, regarded as a straight line, to represent

Is there any change in the terrestrial axis with respect to the matter of the earth? Why?

189. What is nutation, and by what caused? Who discovered it?

190. What incident led to the discovery that there is an apparent change in the position of the heavenly bodies? By what caused? What is this apparent change called?



the distance through which the earth is carried in one second of time, and a E″ the distance through which a particle of light, coming from the sun or star S, moves in the same time. When the earth is at E, the particle of light entering the axis of a telescope at a, will descend in this axis while it keeps parallel to itself, and moves from E to E″; hence at E, E′ and E″, the star will appear successively at s, s' and s''. Now when the earth is at E″, the true position of the star is in the direction E″ S, and the apparent position in the direction E″ s''. Therefore the angle S E″ s'', or its equal, E″ a E, expressing the apparent change of the star S from its true place, caused by the combined motions of light and the earth, is the aberration of the star. The motion occasioned by the rotation of the earth on its axis is disregarded, because it is so small, compared with the annual motion, as to produce no sensible effect.

191. Amount of Aberration.

Since the mean rate of the earth's motion in its orbit per hour is 68186 miles (84), we have $1h. : 1s. :: 68186m. : 19$ miles nearly, the orbitual velocity of the earth per second. The velocity of light per second is 192961 miles (142); hence the triangle E a E″ (see last fig.) gives a E″ : E E″ :: *sin* a E E″ : *sin* E a E″ = *sin* S E″ s''; but a E″ : E E″ :: velocity of light : velocity of the earth :: 192961 : 19. Hence 192961 : 19 :: *sin* a E E″ : *sin* S E″ s''. Therefore,

$$\sin \text{S E}'' s'' = \frac{19}{192961} \sin a \text{ E E}''.$$

But since the length of radius is 206264″, and also since the

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Draw the diagram, and explain the theory.

191. What is the orbitual velocity of the earth per second? Knowing this and the velocity of light per second, how is the aberration found?

angle S E″ s″ is very small, and may be taken for its sine, it follows that,

$$S\,E''\,s'' = \frac{19 \times 206264''}{192961}\ sin\ a\ E\ E'' = 20''.3\ sin\ a\ E\ E''.$$

The aberration increases as the angle *a* E E″ increases, and evidently takes place in a direction parallel to, and in the same way as, that of the earth's motion. When the angle *a* E E″ is 90°, the aberration is a maximum, or 20″.3, which is nearly the constant aberration in longitude with regard to the sun; but for a planet, the aberration will be affected by the planet's motion during the time that the light is passing from it to the earth. As the directions of the earth's motion are opposite at opposite seasons of the year, the amount of aberration of a star may be 20″.3 × 2 = 40″.6.

The aberrations of the stars found by observations made at opposite seasons of the year, correspond with the computed deviations, and hence we have not only a proof of the *uniform transmission* of light, but that the orbitual motion of the earth is a *truth* susceptible of the strictest demonstration.

CHAPTER XIX.

ECLIPSES OF THE SUN AND MOON. OCCULTATIONS OF THE FIXED STARS.

192. Causes of Solar and Lunar Eclipses. An eclipse of the sun is occasioned by the moon coming between the earth and the sun, so as to intercept his light, that to any place on the earth the sun may appear partly

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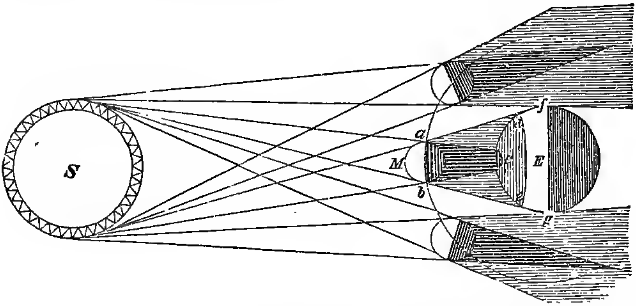
What is the constant aberration in longitude with regard to the sun? What will affect the aberration of a planet? What may be the amount of aberration of a star? Do the observed aberrations and computed deviations of the stars agree? What does this fact prove?

192. What occasions an eclipse of the sun?

or wholly covered. This privation of the sun's light is nothing more than the moon's shadow falling on the earth at the place of observation; hence, all solar eclipses happen at the time of new moon. An eclipse of the moon is occasioned by the earth coming between the sun and the moon, so as to deprive her of the sun's light, or by the moon entering into the earth's shadow; hence all lunar eclipses must happen when the moon is in opposition to the sun, or at the time of full moon.

193. Solar Eclipses. The phenomenon of a solar eclipse may be better understood as to its nature and cause, by reference to the following figure, where S represents the sun, E the earth, and M the moon, at the change, or in conjunction.



Having drawn the common tangents on the same and different sides of the sun and moon, and therefore limiting the real and partial shadows of the latter body, it is evident that the dark shadow of the moon will be of a conical form because she is globular and much smaller than the sun whose rays of light she obstructs. The

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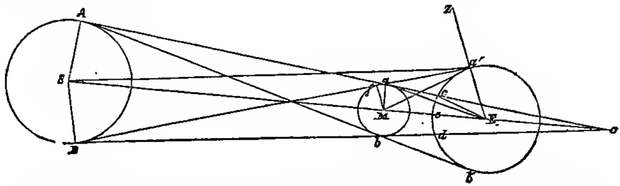
When do all solar eclipses happen? What occasions an eclipse of the moon? When must all lunar eclipses happen?

193. Show by drawing the diagram, how the real and partial shadows of the moon are limited. Why will the dark shadow be of a conical form?

dark conical shadow *a b c* of the moon is called the *umbra,* and at *c* on the earth's surface where it falls, the eclipse of the sun will be total. The bright or partial shadow at *a d b e*, which surrounds the umbra, is called the *penumbra,* and at *d e*, where it falls, there will be a partial eclipse ; but, at all other places of that hemisphere of the earth turned towards the sun on which the penumbra does not fall, there will be no eclipse.

194. LENGTH OF THE MOON'S SHADOW.

Let A B, *a b*, and *a′ b′* be sections of the sun, moon, and earth, made by a plane passing through their centres S, M, and E in the same straight line. Also, let the common tangents be drawn to the same and different sides of the sections of the sun and moon, and therefore limiting the sections of the umbra and penumbra.



The sun and moon will have the same apparent semi-diameter as seen from C, the vertex of the shadow, and this semi-diameter of the sun, namely, the angle S C A, or M C *a*, will be very nearly the same as that seen from E the centre of the earth, because the distance C E, even when it is the greatest, is small when compared with the great distance of the sun.

Put d = angle M C a = the sun and moon's ap. semi-diam. as seen from C,
d' = angle M E a = the moon's ap. semi-diam. as seen from E,
L = M C = the length of the shadow, and
D = M E = the moon's distance in radii of the earth.

What is the dark shadow called? What the partial shadow? Show where there will be a total eclipse, and where a partial one?

194. Draw the diagram, and fully explain how the length of the moon's shadow is found. When is the length of the shadow greatest?

Now since the apparent semi-diameters of the moon as seen from C and E, namely, the angles M C a and M E a, are inversely proportional to the distances M C and M E, we have,

$$\text{M C } a : \text{M E } a :: \text{M E} : \text{M C},$$
$$\text{or,} \quad d : d' :: \text{D} : \text{L},$$
$$\text{whence L} = \text{D} \frac{d'}{d}.$$

By using the proper values for D, d' and d (97, 107, 85), the shadow will be found, when the sun is in apogee and the moon in perigee, to extend about 3.5 radii of the earth beyond its centre. But when the sun is in perigee and the moon in apogee, the shadow will want 6.3 radii of reaching the earth's centre.

195. Greatest Breadth of the Moon's Shadow at the Earth.

When the shadow would extend to the greatest distance beyond the earth's centre, its breadth at the surface will evidently be the greatest. From c, (see the last fig.) the point where the tangent A C would cut the earth's surface, draw c E; then we have in the triangle c E C, the side E C = M C — M E = $\text{D} \frac{d'}{d} - \text{D} = \left(\frac{d'}{d} - 1\right) \text{D}$, c E = 1, the radius, and the angle E C $c = d$ the sun's least semi-diameter, to find the angle E c C. Thus,

$$\text{E } c : \text{E C} :: \sin \text{E C } c : \sin \text{E } c \text{ C},$$
$$\text{or } 1 : \left(\frac{d'}{d} - 1\right) \text{D} :: \sin d : \sin \text{E } c \text{ C}.$$

By using the small angles d and E c C, instead of their sines, we have,

$$1 : \left(\frac{d'}{d} - 1\right) \text{D} :: d : \text{E } c \text{ C} = (d' - d) \text{ D}.$$

The value of $(d' - d)$ D will give for the angle E c C 56′ 22″. But the exterior angle e E c = E c C + E C c = 56

What is its extent then? When is the length of the shadow least? How far does it want then of reaching the earth's centre?

195. When will the breadth of the shadow at the earth's surface be the greatest? Explain by the diagram, the method of finding its breadth?

22″ + 15′ 45″ = 1° 12′ 7″ = the arc *e c*; and 2 *e c* = *c d* = 2° 24′ 14″ = 166 miles, the greatest breadth or diameter of the circular portion of the earth's surface ever covered by the moon's umbra. If the moon is at some distance from the node, the shadow will fall obliquely on the earth's surface, and will therefore cover an extent exceeding the above distance.

196. GREATEST BREADTH OF THE PENUMBRAL SHADOW AT THE EARTH.

The breadth of the moon's penumbra will evidently be the greatest, when the sun is in perigee, and the moon in apogee. From a' (see the last fig.) where the common tangent B f would cut the earth's surface, draw E a' and produce it to Z, also draw a' S and a' M. The angle a' M E = S a' M + a' S M; but S a' M = S a' B + f a' M = $d + d'$, the sun and moon's apparent semi-diameters as seen from a', and a' S M, the sun's parallax in altitude at a' being so small, may be disregarded; therefore a' M E = $d + d'$ = 16′ 17″.3 + 14′ 41″ = 31′ nearly. Now the angle a' M E is the moon's parallax in altitude at a', and M a' Z is the zenith distance at the same place; hence (54), we have,

sin H 53′ 51″ (55) *ar. co.* -	1.8051059
: Radius	10.0000000
: : *sin p*, 31′ -	7.9550819
: *sin* M a' Z 35° 9′ -	9.7601878

The angle a' E M = M a' Z — a' M E = 35° 9′ — 31′ = 34° 38′ = the arc a' e, and 2 a' e = a' b' = 69° 16′ = 4800 miles, nearly, the greatest breadth of the portion of the earth's surface ever covered by the penumbra.

197. GREATEST BREADTH OF THE PART OF THE EARTH'S SURFACE, AT WHICH THE ECLIPSE CAN BE ANNULAR.

Let A S B, *a m b*, and a' E b', be sections of the sun, moon,

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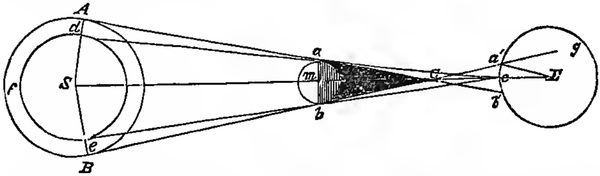
What is the greatest breadth of the earth's surface that can ever be covered by the umbra?

196. When will the breadth of the moon's penumbral shadow at the earth be the greatest? Explain by the diagram the method of finding its breadth. What is the greatest breadth of the earth's surface that can ever be covered by the penumbra?

and earth, also A a and B b common tangents to the sun and moon, intersecting at C before meeting the earth at a' and b'. From c, where the axis of the shadow produced meets the earth's surface, draw $c\ d$ and $c\ e$, tangents to the moon.



It is evident that to an observer at c, or any other point of the earth's surface between a' and b', the moon will cover the central part of the sun, leaving a luminous ring, as $d\ e\ f$, unobscured. In the triangle a' C E, we have the angle a' C E = S C B, the sun's apparent semi-diameter, as seen from C, which may be regarded the same as seen from the earth, C E = 6.3 radii of the earth, or the distance of the apex of the conical shadow from the centre (194), and a' E = 1, or the earth's radius, to find the angle a' E C. Thus:

	a' E, 1 -	.0000000
:	E C, 6.3 - -	.8000294
: :	sin a' C E, 16′ 17″ - -	7.6754678
:	sin $g\ a'$ E, 1° 42′ 46″ -	8.4754972

But c E a' = $g\ a'$ E — a' C E = 1° 42′ 46″ — 16′ 17″ = 1° 26′ 29″ = the arc $a'\ c$, and 2 $a'\ c$ = $a'\ b'$ = 2° 52′ 58″ = 199 miles, the greatest breadth of the part of the earth's surface at which the eclipse can be annular.

198. ECLIPTIC LIMITS OF THE SUN.

Let A B and $a\ b$ represent sections of the sun and earth, made by a plane passing through their centres S and E. Draw the tangents A a and B b limiting the section, made by this plane, of the frustum of a cone formed by rays tangent to the sun and earth; and describe $m\ m'$ a portion of the moon's or-

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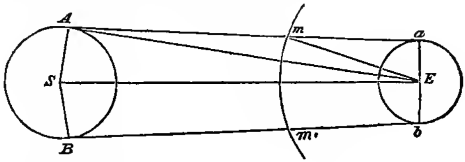
197. Draw the diagram and calculate the greatest breadth of the part of the earth's surface at which the eclipse can be annular.

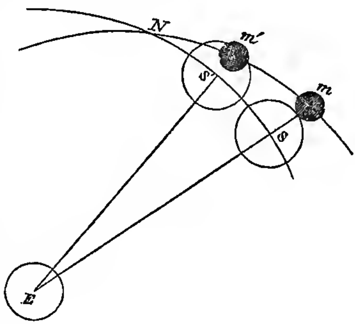
bit about the centre E, with a radius equal to her distance from the earth at the time of conjunction.



It is evident that whenever the moon comes within the frustum A *a* *b* B, there will be an eclipse of the sun somewhere on the earth's surface. From *m*, where the moon's orbit intersects A *a*, draw *m* E, and the angle *m* E S will be the apparent semi-diameter of the frustum at the distance of the moon as seen from E, the earth's centre. Now the angle $m\text{ E S} = \text{A E S} + m\text{ E A} = \text{A E S} + \text{E } m\ a - m\text{ A E}$; but $\text{A E S} = d$, the sun's apparent semi-diameter, $\text{E } m\ a = \text{H}$, the moon's horizontal parallax, and $m\text{ A E} = p$, the sun's parallax; therefore, $m\text{ E S} = d + \text{H} - p$.

If the moon's orbit were in the plane of the ecliptic, there would be an eclipse of the sun at every new moon; but since it is inclined to it, an eclipse cannot occur, unless the moon's latitude (18) be less than the sum of her apparent semi-diameter d', at the time of conjunction, and the apparent semi-diameter of the luminous frustum at her orbit.

Let N S, N *m*, represent portions of the ecliptic and moon's orbit referred to the celestial sphere, N the descending node, S, S′ transverse sections of the luminous frustum corresponding to the direction of the sun from E, the earth, and *m*, the place of the moon in conjunction, when her latitude, which call $l = d + \text{H} - p + d'$. It is evi-



198. Draw the diagram, and demonstrate that the apparent semi-diam-

dent the moon will not obscure any portion of the sun at the time of conjunction, unless she is in a position as *m'* nearer the node than *m*, and consequently her latitude less than *m* S. In the right angled spherical triangle *m* N S, we have the angle *m* N S, equal to the inclination of the moon's orbit, which has its greatest value at the time of syzygies, namely, 5° 17′ (102), and *m* S = *l*, to find S N, the difference between the longitude of the node and that of the sun or moon. Thus. Radius : co-tang. *m* N S : : tang. *l* : sin S N. Taking, therefore, 5° 17′ for *m* N S, and the greatest and least values of *l*, the above proportion will give for the greatest value of S N, 17° 17′, and for the least, 15° 21′.

Hence at the time of new moon, if the difference between the longitude of the nearest node and that of the sun or moon, exceeds 17° 17′ there cannot be an eclipse of the sun; but if the difference is less than 15° 21′, there must be an eclipse. These are the *solar ecliptic limits*. Should the difference in longitude fall between these numbers, farther calculations become necessary to determine whether there will or will not be an eclipse.

199. Different kinds of Solar Eclipses. When the moon changes in perigee, and within the solar ecliptic limits, she appears large enough to cover the whole of the sun's disc, from those places of the earth on which her dark shadow falls; and, consequently, there the eclipse of the sun will be *total.* But when the moon changes in apogee, and within the solar ecliptic limits, she appears less than the sun, and therefore cannot cover his whole

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eter of the luminous frustum formed by the rays tangent to the sun and earth, at the distance of the moon as seen from the earth's centre, is equal to the sum of the sun's apparent semi-diameter, and the difference of the sun and moon's horizontal parallaxes. If the moon's orbit were in the plane of the ecliptic, how often would there be an eclipse of the sun? In order that an eclipse may occur, what must the moon's latitude be less than? Draw the diagram and calculate the ecliptic limits of the sun. When can there not be an eclipse of the sun? When must there be one? When does it become necessary to make farther calculations whether there will or will not be an eclipse?

199. When and at what places can the eclipse of the sun be total?

disc from any part of the earth; and at that place of the earth which is in a straight line with the centres of the sun and moon, a person would see the edge of the sun round the dark body of the moon, appearing like a luminous ring, called an *annular* eclipse. If a part only of the sun's disc is obscured, the eclipse is a *partial* one. At all those places of the earth, over which the axis of the shadow, or the straight line connecting the centres of the sun and moon produced, passes, the eclipse will be *central.* When an eclipse of the sun is considered with respect to the whole earth, and not with respect to any particular place, it is called a *general* eclipse.

200. VISIBILITY OF SOLAR ECLIPSES. As the moon moves in her orbit from west to east, her shadow will also move over the earth's surface in the same direction; hence the eclipse must begin earlier at the western parts than at the eastern; hence also the eclipse begins on the western edge of the sun, and ends on the eastern. Since the moon's penumbra is tangent to the earth, where the eclipse begins and ends, (the eclipse begins at *f* and ends at *g*, see fig. page 154), it follows that at the place where the eclipse is first seen, the sun will be just rising; and where it is last seen, he will be setting. At all those places over which the axis of the shadow passes, or those contiguous to them, the eclipse will be either total or annular, according as the moon's apparent diameter is greater or less than that of the sun; but if the axis of the shadow does not meet the earth, which is the case when the moon changes far from the node, and yet within the ecliptic limit, there will be no central eclipse at any place,

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When and where can it be annular? What is a partial eclipse? When will the eclipse be central? What does a general eclipse respect?

200. Why does the eclipse begin earlier at the western parts of the earth than at the eastern? On what edge of the sun does the eclipse begin, and on what edge end? Where will the sun appear at the place where the eclipse is first seen? Where at the place it is last seen? Where will the eclipse be either total or annular? When will there be no central eclipse at any place, and where will there be but a partial one?

and the partial eclipse will be visible only in a portion of the northern or southern hemisphere, according as the moon's latitude is north or south. To a great portion of the enlightened hemisphere of the earth, the eclipse will be invisible, because the breadth of the penumbra, even when greatest, (196), is less than half the semi-circumference of the earth.

201. Duration of Solar Eclipses. The general eclipse will commence the instant that the moon's eastern edge touches the luminous frustum A *a* B *b*, (see fig. page 159), and will continue until her western edge leaves it; hence the general eclipse of longest continuance will last during the period of time required for the moon to make an advance in longitude over the sun equal to the sum of the diameters of the frustum and moon, or equal to $2\ (d + H - p + d')$. It has been found that the longest duration of a general eclipse is about six hours.

In a total eclipse, the velocity of the moon's dark shadow at the earth's surface, will be equal to its breadth in the time required for the moon to advance in longitude over the sun equal to $2\ (d' - d)$, or the difference in their apparent diameters; but since any point of the earth's surface, where the shadow falls perpendicularly, moves in the same direction with the shadow, caused by the rotation of the earth on its axis, we must determine the time required for the shadow to pass over this point, taking their respective velocities into consideration. The greatest duration of a total eclipse at any one place, is about eight minutes. The duration of an annular eclipse may be determined in a similar manner, by finding the breadth of the earth's surface at which the eclipse can be annular at the same time, and using the quantity $2\ (d - d')$ for

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Why will there be no eclipse to a great portion of the enlightened hemisphere of the earth?

201. What is the longest duration of a general eclipse? Explain this by referring to the figure. What is the greatest duration of a total eclipse at any one place, and how determined? How is the duration of an annular eclipse determined?

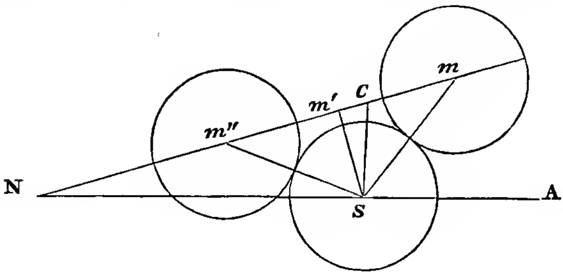
the moon's advance in longitude over the sun. An annular eclipse at any one place, cannot last more than 12½ minutes.

202. COMPUTATION OF SOLAR ECLIPSES FOR THE EARTH IN GENERAL.

A solar eclipse will begin and end upon the earth, when the distance of the centres of the sun and moon before and after conjunction, is equal to $H - p + d + d'$ (198); the total eclipse will begin and end when this distance is equal to $H - p - d + d'$; and the annular eclipse when it is equal to $H - p + d - d'$.

From the proper tables the proximate time of new moon may be found; and for this time, by means of solar and lunar tables, the longitude of the sun, the latitude and longitude of the moon, the sun and moon's hourly motion, their apparent semi-diameters, and their horizontal parallaxes, may be computed. Knowing the sun and moon's longitudes at the proximate time of new moon, and their hourly motions in longitude, the true time of conjunction is easily found. And, knowing the true time of conjunction, the moon's latitude at the proximate time, and her hourly motion in latitude, her latitude at the true time of conjunction is also easily found.

Let A N represent the ecliptic, S the sun, and $m\,m''$ the moon's *relative orbit*, or the moon's motion relative to the sun during the eclipse on the supposition that S remains stationary.



What is its longest duration at any one place?

202. What is the distance of the centres of the sun and moon, when a solar eclipse begins and ends upon the earth? What when the total eclipse begins and ends? The annular? How is the proximate time of

Draw S C and S m' respectively perpendicular to S N and N m, and lay off S m and S m'', each equal to H — p + d + d'; then S C will represent the moon's latitude, and C the place of her centre at the time of conjunction, S N her relative motion in longitude, C N her motion in her relative orbit, m m' and m'' the places of her centre at the beginning, middle, and end of the eclipse. We may regard the lines necessarily small, composing the figure, as straight lines without material error, and also the sun and moon's motion as uniform during the continuance of the eclipse.

Put $s = H - p + d + d'$,
$s' = H - p - d + d'$,
$s'' = H - p + d - d'$,
h = the moon's hourly motion in long. less the sun's do.,
h' = the moon's hourly motion in latitude,
T = the time of conjunction, or new moon,
l = the moon's latitude at new moon,
I = the inclination of the moon's relative orbit,
h'' = the moon's hourly motion in her relative orbit,
t = the interval between time of conjunction and middle of the eclipse,
t' = the interval between middle and beginning or end,
M = the middle of the eclipse,
B = the beginning of the eclipse,
E = the end of the eclipse.

The quantities represented by s, s', s'', h, h', T and l, are known, and from these, the quantities represented by I, h'', t, M, t', B and E are derived.

In the triangle C N S, we have,

N S : C S :: Radius : tang C N S,

or, $h : h' :: 1 : \text{tang I} = \frac{h'}{h}$; and

Radius : sec C N S :: N S : C N,

or $1 : \sec I :: h : h'' = \sec I \, h = \frac{h}{\cos I}$; hence $C\,m' = \frac{h}{\cos I}\,t$.

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new moon found? From this time, by means of solar and lunar tables, what may be computed? How is the true time of conjunction found? The moon's latitude at the true time of conjunction? Draw the diagram

Because, the triangle C m' S is similar to the triangle C N S, and right angled, we have the angle C S m' = C N S = I, and C m' = C S *sin* C S m'; therefore, C m' or its equal.

$$\frac{h}{\cos \mathrm{I}} t = l \sin \mathrm{I}; \text{ whence}$$

$$t = \frac{l \sin \mathrm{I}}{\frac{h}{\cos \mathrm{I}}} = \frac{l \sin \mathrm{I} \cos \mathrm{I}}{h} =$$

$$\frac{3600s.\ l \sin \mathrm{I} \cos \mathrm{I}}{h} \text{ expressed in seconds; hence,}$$

$$\mathrm{M} = \mathrm{T} \pm t = \mathrm{T} \pm \frac{3600s.\ l \sin \mathrm{I} \cos \mathrm{I}}{h} \text{ the true}$$

time of the middle of the eclipse. When the latitude is decreasing the *upper* sign must be used, and when it is increasing the *lower* sign.

From the right angled triangles C m' S and $m\,m'$ S, we have,

$$m' \mathrm{S} = \mathrm{C\ S} \cos m' \mathrm{S\ C} = l \cos \mathrm{I}, \text{ and}$$

$$m\,m' = \sqrt{m\,\mathrm{S}^2 - m'\,\mathrm{S}^2} = \sqrt{(m\,\mathrm{S} + m'\,\mathrm{S})\,(m\,\mathrm{S} - m'\,\mathrm{S})};$$

$$\text{but } m\,m' = \frac{h}{\cos \mathrm{I}} t'; \text{ whence}$$

$$t' = \frac{\cos \mathrm{I}}{h} \sqrt{(s + l \cos \mathrm{I})\,(s - l \cos \mathrm{I})}; \text{ therefore}$$

$\mathrm{B} = \mathrm{M} - t'$, and $\mathrm{E} = \mathrm{M} + t'$ become known.

The interval for a total or annular eclipse may be found by using s' or s'', as the case may be, instead of s in the above formula.

203. Computation of Solar Eclipses for a Particular Place.

The circumstances of an eclipse at a given place, depend on the *apparent* relative position of the sun and moon as seen from that place; hence the effect of parallax must be regarded in changing the apparent relative position of these bodies. The calculation then, of the time when the eclipse has any given

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and illustrate these principles. Point out the known and unknown quantities in this problem, and show how the latter are derived from the former.

203. On what do the circumstances of a solar eclipse at a given place depend? What must be regarded?

phase, consists in finding the time when the apparent distances of the centres of the sun and moon, has a value equal to the sum or difference of their apparent semi-diameters, answering to the given phase of the eclipse.

In the computation it is customary, because the sun's parallax is very small, to regard the true longitude of the sun as the apparent longitude, and to employ the difference between the parallax of the moon, and that of the sun, called the *relative parallax,* as the parallax of the moon.

Let T′ be the proximate time of new moon, and for this time compute by the tables the quantities mentioned in Article 202; also by means of the hourly motions, find the sun's longitude, and the moon's longitude and latitude for the time, an hour earlier than the time T,′ or for T′ — 1*h*. From the moon's horizontal parallax, reduced from the equator to the given place, subtract the sun's horizontal parallax, and denote the remainder by H — *p*. Using the latter quantity, find the moon's parallaxes for the times T′ and T′ — 1*h*., and thence also her apparent longitudes and latitudes for these times. The difference between these apparent longitudes of the moon will give her apparent hourly motion in longitude, and this less the sun's hourly motion, will give the moon's apparent relative hourly motion *h*. Also, the difference between these apparent latitudes of the moon, will give her apparent hourly motion in lattude *h*′. Knowing the apparent relative hourly motion in longitude, and the difference between the sun's longitude and the moon's apparent longitude, at the time T′ — 1*h*., the time of apparent conjunction can easily be found. For this time, which is but an approximation to the truth, because the moon's apparent motions are not regular, find the moon's apparent longitude and latitude, and also the moon's distance from apparent conjunction, which will now be very small. Then by means of the relative hourly motion, the true time T of conjunction can be found; and by means of the moon's hourly motion in latitude, her latitude *l* for this time can also be found. Hence, by using these apparent elements answering to the true, and the sum of the apparent semi-diameters of the sun and moon, $d + d' = s$, it is evident, that the time of the middle or greatest

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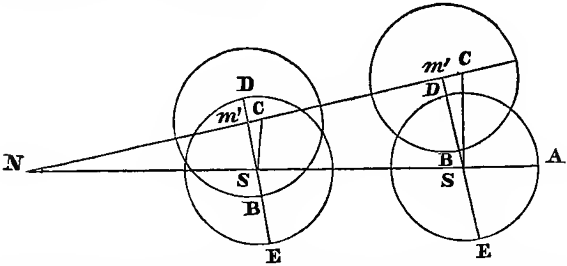
On what does the calculation of the time, when the eclipse has a given phase, consist? What is customary in the computation? Show how the apparent elements, *h*, *h*′, T and *l*, may be found? By using these ele obscuration, and the times of the beginning and end of the eclipse, may be calculated in the same manner as in the general eclipse.

204. Quantity of a Solar Eclipse at a Particular Place. In a partial eclipse, the number of digits (21) obscured at the time of the middle of the eclipse in that diameter of the sun, which when produced, if necessary, would apparently pass through the moon's centre, denotes the quantity of the eclipse.



Thus let m' represent the moon's centre at the time of greatest obscuration, then the digits contained in B D will express the quantity of the eclipse. Put B D = Q, and we have,

$$DE : BD :: 12 : Q,$$

$$\text{or, } 2d : BD :: 12 : Q = \frac{6\,BD}{d}.$$

But $BD = SD + Bm' - Sm'$ (202) $= d + d' - l \cos I$;

$$\text{therefore } Q = \frac{6\,(d + d' - l \cos I)}{d}.$$

If the nearest distance between the centres of the sun and moon, or the apparent latitude of the moon at conjunction, multiplied by the cosine of the inclination of her apparent relative orbit, exceeds the sum of the apparent semi-diameters of the sun and moon, or if $l \cos I > d + d'$, there will be no

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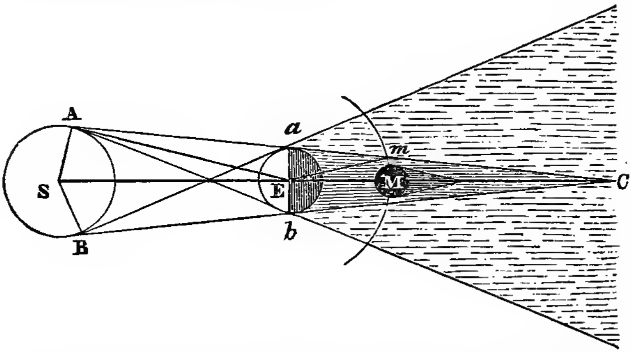
ments and the sum of the sun and moon's apparent semi-diameters, what may be calculated?

204. What denotes the quantity of the eclipse at a particular place? Draw the diagram, and show how the quantity may be found. When

eclipse. If this distance is intermediate between $(d + d')$ and $(d \sim d')$, there will be a partial eclipse; and if it is less than $(d \sim d')$, the eclipse will be annular or total, according as d is greater or less than d'.

205. Lunar Eclipses. The nature and cause of a lunar eclipse may be understood by reference to the following figure, where S represents the sun, E the earth, and M the moon in opposition.



Having drawn the common tangents on the same and different sides of the sun and earth, it is evident that the eclipse of the moon M, will be *total* as long as she is wholly immersed in the real shadow or umbra *a b* C of the earth. Should a part of the moon, but not the whole, enter the shadow, the eclipse will be *partial;* and should she pass but through the penumbra, she will suffer a diminution of light but not an eclipse. Since an eclipse of the moon is occasioned by a real loss of her light, it will be visible to every part of that hemisphere of the earth, which is turned next her.

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will there be no eclipse? When will the eclipse be partial? And when total or annular?

205. How may the nature and cause of a lunar eclipse be better understood? Describe a total and partial eclipse? Where will an eclipse of the moon be visible?

On account of the penumbra which surrounds the umbra to a certain distance, the moon will become sensibly paler and dimmer before entering the real shadow of the earth, and on receding from it she will as gradually increase in brightness. This circumstance renders it difficult to note the precise times of the beginning and end of the eclipse. The moon, while immersed in the shadow is not wholly invisible, but has a dull reddish appearance. This phenomenon is the effect of the atmosphere refracting certain rays of the sun which enter it, and therefore bending their course towards the axis of the shadow, so that they may fall on the moon, rendering her visible. An eclipse of the moon begins on the eastern limb, and ends on the western. When an eclipse of the moon happens, the sun will be eclipsed to her as long as she continues in the earth's shadow.

206. LENGTH OF THE EARTH'S SHADOW.

If a plane be supposed to pass through the centres S and E of the sun and earth (see the last figure), $a\ b$ C will be a section of the earth's shadow, and E C its *axis*, or the distance it extends. Put E C = L, and E $a = r$, the radius of the earth. The right angled triangle E C a gives,

$$\sin \text{E C} a : \text{Radius} :: \text{E} a : \text{E C},$$

$$\text{or} \sin \text{E C} a : 1 :: r : \text{L} = \frac{r}{\sin \text{E C} a}.$$

But E C a = S E A − E A $a = d - p$; therefore

$$\text{L} = \frac{r}{\sin (d - p)} = \frac{1}{\sin (d - p)}\, r = \frac{206264''}{d - p}\, r.$$

When $d - p = 16'\ 17'' - 8''.6 = 16'\ 8''.4$ a maximum, L = $213r$ a minimum. The greatest distance of the moon is $64r$, nearly; hence the length of the earth's shadow must always be more than 3 times the distance of the moon.

What renders it difficult to note the precise times of the beginning and end of the eclipse? Is the moon wholly invisible while immersed in the earth's shadow? And why? On which limb does the eclipse begin and end? What occurs to the moon when she is eclipsed to us?

206. Calculate from the last figure the minimum extent of the earth's shadow. What is its length compared to the moon's distance?

207. SEMI-DIAMETER OF THE EARTH'S SHADOW

If an arc be described about E, (see the last fig.), with a radius equal to the moon's distance from the earth at the time of opposition: the arc M m or the angle M E m, the apparent semi-diameter of the earth's shadow at the moon, as seen from E, the earth's centre, is called the Semi-diameter of the Earth's Shadow. The angle M E m = E m a — E C m = H — (d — p) (206) = H + p — d. That is, the semi-diameter of the earth's shadow is equal to the sum of the sun and moon's horizontal parallaxes, *minus* the sun's apparent semi-diameter.

When the sun is in perigee, and the moon in apogee, H + p — d = 53′ 51″ + 8″.6 — 16′ 17″.3 = 37′ 42″.3, the minimum value of the semi-diameter of the shadow; hence the diameter of the shadow is always more than twice the apparent diameter of the moon, and consequently more than sufficient entirely to envelope her.

The expression H + p — d is obtained on the supposition that the conical shadow of the earth is bounded by those rays from the edge of the sun which are tangent to the earth's surface. This is not the exact case, because the observed duration of eclipses has been found to exceed the duration computed on this supposition. To account for this circumstance, the solar rays, which pass near the earth's surface, are supposed to be absorbed by the lower strata of the atmosphere; and hence the diameter of the shadow, and consequently the duration of the eclipse, would be increased. On this account, it is customary, in calculating lunar eclipses, to increase the computed semi-diameter $\frac{1}{60}$ part, making it equal to H + p — d + $\frac{1}{60}$ (H + p — d).

208. ECLIPTIC LIMITS OF THE MOON.

If the moon's orbit were in the plane of the ecliptic, there would be a lunar eclipse at every full moon; but since it is inclined to it, an eclipse cannot occur unless the moon's latitude

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207. Find the expression for the semi-diameter of the earth's shadow at the moon. When is it a minimum, and what is then its amount? What is the consequence of this? Why is it customary, in calculating lunar eclipses, to increase the computed semi-diameter $\frac{1}{60}$ part?

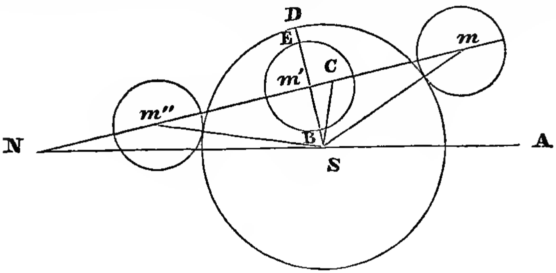
208. If the moon's orbit were in the plane of the ecliptic, how often would there be a lunar eclipse?

be less than the sum of her apparent semi-diameter, at the time of opposition, and the corrected semi-diameter of the earth's shadow. Thus $H + p - d + \frac{1}{60}(H + p - d) + d'$ will express the greatest latitude of the moon at opposition, when a lunar eclipse can happen.

The figure on page 159, illustrating the solar ecliptic limits, may be here used by supposing S and S′ transverse sections of the earth's shadow, E the earth, and m the moon in opposition, when her latitude $m\,S = H + p - d + \frac{1}{60}(H + p - d) + d' = l$. Taking 5° 17′ for m N S, the inclination of the orbit, and the greatest and least values of l, which are respectively 63′ 24″ and 53′ 1″, the greatest value of S N, or the greatest limit will be 11° 30′, and the least, 9° 36′. These are the *lunar ecliptic limits.*

209. COMPUTATION OF LUNAR ECLIPSES. From the proximate time of full moon, and the sun and moon's longitudes at this time and their hourly motion in longitude, the true time of full moon is easily found. And knowing the true time of full moon, the moon's latitude at the proximate time and hourly motion in latitude, her latitude at the full is also easily found.

Now the times of the various phases of an eclipse of the moon may be found by a process similar to that used in finding the



What must the moon's latitude be less than, when an eclipse occurs? Draw the figure and show how the lunar ecliptic limits are found. What are the greatest and least lunar ecliptic limits?

209 How is the true time of full moon found? How is her latitude at full also found?

times of a solar eclipse (202) for the earth in general. Thus let S represent the stationary centre of the earth's shadow, and $m\ m''$ the moon's relative orbit. Lay off S m and S m'' each equal to $H + p - d + \frac{1}{60}(H + p - d) + d'$, and draw S C and S m' respectively, perpendicular to S N and m N. We shall have as in the eclipse of the sun,

$$M = T \pm \frac{3600s.\ l \sin I \cos I}{h},$$

$$B = M - \frac{\cos I}{h} \sqrt{(s + l \cos I)(s - l \cos I)}, \text{ and}$$

$$E = M + \frac{\cos I}{h} \sqrt{(s + l \cos I)(s - l \cos I)}.$$

In the above formulæ, $s = H + p - d + \frac{1}{60}(H + p - d) + d'$, and the other letters represent quantities of the same name as in the solar eclipse, but at *opposition* instead of conjunction.

210. Quantity of a Lunar Eclipse.

In a partial eclipse, the number of digits obscured at the time of the middle of the eclipse in that diameter of the moon which, when produced, would pass through the centre of the earth's shadow, denotes the quantity of the eclipse. When, as in a total eclipse, the moon passes entirely within the shadow, the quantity is expressed by the number of digits contained in the same diameter when prolonged to the nearest edge of the shadow. Thus the number of digits contained in B D (see the last fig.) will express the quantity of the eclipse. Put B D = Q, and we have,

$$B E : B D :: 12 : Q,$$

$$\text{or } 2\,d' : B D :: 12 : Q = \frac{6 B D}{d'}$$

But $B D = S D + B m' - S m' =$
$H + p - d + \frac{1}{60}(H + p - d) + d' - l \cos I =$
$s - l \cos I$; hence

$$Q = \frac{6(s - l \cos I)}{d'}.$$

From the data used in finding the times of a solar eclipse, find the times of the phases of a lunar eclipse.

210. What denotes the quantity of a lunar elipse when partial? What when total? Draw the diagram and find the formula expressing the

If l cos I exceeds s, there will be no eclipse. If it is less than s, and greater than $s - 2\,d'$, the eclipse will be partial; and if less than $s - 2\,d'$, it will be total.

211. Period of Eclipses. Since the moon's node retrogrades 19° 20′ in a year, (103) we have 360° + 19° 20′ : 360° : : 365.25d : 346.6 days, the mean period in which the sun moves from any node to the same again. This period of the sun's revolution, with respect to the moon's node, and 29.53 days the period of one lunation, are very nearly in the ratio of 223 to 19; therefore the sun's distance from either node at the time of any new or full moon, after the lapse of 223 lunations, will be very nearly equal to his distance from the same node, at the commencement of this period. Hence after the expiration of 223 lunations, equal to 18 years 11 days, eclipses, both of the sun and moon, must occur again in nearly the same order and at the same intervals as during that time, which is therefore called the *Period of Eclipses.*

This period was known to the Chaldean and Egyptian astronomers, by whom it was called *Saros,* and was very useful in predicting eclipses.

212. Number of Eclipses in a Year. There cannot be more than seven eclipses, nor fewer than two, in one year. When there are seven, five of these are of the sun, and two of the moon; but when only two, both are of the sun. The usual number is four.

The sun's mean motion in longitude during a synodic month,

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quantity. Show when there will be no eclipse. When it will be partial and total.

211. What is the mean period in which the sun moves from any of the moon's nodes to the same again? Explain this. In what ratio are this period and one lunation? What follows from this? And hence what must occur again after the expiration of 223 lunations? What is this period called? To whom known, and for what useful?

212. What is the greatest and least number of eclipses that can occur in a year? In these cases, how many of the sun and how many of the moon? What is the usual number?

is 29° 4′, and the moon's nodes retrograde in the same time 1° 32′; hence the sun's motion, with respect to either node, is 30° 36′ in one lunation, and 15° 18′ in half a lunation. If we suppose the sun to be at a little less distance than 17° 17′ (198) from the node which he is approaching, at the time of new moon and soon after the beginning of the year, he may be eclipsed; and the moon, at the subsequent opposition, being nearly 2° from the other node, will be largely eclipsed, and come round to the next conjunction, when the sun is a little more than 13° in advance of the former node: thus during the period of a month, there may be three eclipses, two of the sun and one of the moon. There will not be another eclipse until at the next new moon which occurs at the opposite node after five lunations, when the longitude of this node will be nearly 14° in advance of the sun's longitude; hence at this period there may be also two eclipses of the sun and one of the moon. After five lunations again from the last new moon, and therefore a little before the close of the year, the longitude of the sun will be but about 10° less than that of the first node, and consequently he will be eclipsed. Hence in the case assumed, there may be seven eclipses in the year, five of the sun and two of the moon. But if we suppose the sun to have about 2° less longitude than the node at the time of new moon, and about one month after the beginning of the year, he will not be near enough the same node again to be eclipsed before the close of the year. In this case, as the moon will change after six lunations, very near the opposite node, there will two eclipses of the sun in the year; and there will be none of the moon, because, at the contiguous full moons, she will be at a distance from the nodes greater than the lunar ecliptic limits.

The sun's ecliptic limits are greater than the moon's, consequently there will be more solar than lunar eclipses; yet there are more visible eclipses of the moon than of the sun, because every lunar eclipse is visible to every part of that hemisphere of the earth which is turned next

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When there are seven, prove that five are of the sun, and two of the moon. When but two, that both are of the sun. Why are there more solar than lunar eclipses? Why, then, are there more visible eclipses of the moon than of the sun?

her, at the same time; but a solar eclipse is only visible to that part of the earth on which the moon's shadow falls.

213. Occultations. When the moon passes directly between the earth and a star or planet, and thereby renders it invisible somewhere upon the earth, the star or planet is said to suffer an *occultation* from the moon.

Since the stars have neither sensible parallaxes nor apparent diameters, it follows that an occultation for the earth in general will begin and end when the true distance of the moon's centre from the star, before and after conjunction, is equal to $H + d'$, as expressed in the articles on solar eclipses. The greatest value of $H + d' = 61' 29'' + 16' 45'' = 1° 18' 14''$; hence if the distance between the moon's centre and the star, at the time of conjunction, exceeds this quantity, the star cannot be eclipsed. And as the greatest inclination of the moon's orbit or her maximum latitude, is 5° 17'; we find that those stars only, whose latitude is less than $5° 17' + 1° 18' 14'' = 6° 35' 14''$, can be occulted.

By allowing for the inequalities of the moon's motions, and taking the greatest and least values of $H + d'$, it has been found, that if the difference between the latitude of the star and mean latitude of the moon, at the time of their mean conjunction, exceeds 1° 37', there cannot be an occultation; but if this difference is less than 51', there must be one. Should the difference fall between these limits, the true place of the moon must be calculated in order to determine whether there will or will not be an obscuration of the star.

The calculation of an occultation for a given place, is nearly the same as that of a solar eclipse. The star takes the place of the sun's centre, but has neither parallax, semi-diameter, nor

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213. When is a star or planet said to suffer an occultation? What expresses the distance of the moon's centre from a star at the beginning and end of an occultation? What is the greatest value of this expression? Hence what? What of the latitude of those stars which can be occulted? What is farther said on this subject, when allowance is made for the inequalities of the moon's motion? How may an occultation be calculated for a given place?

hourly motion. Instead of the moon's latitude, the difference between the latitude of the star and that of the moon, must be used; and in the place of the apparent difference in the longitudes of the two bodies, we have this difference reduced to an arc between their circles of latitude, and passing through the star parallel to the ecliptic. This reduction is made by multiplying the difference by the cosine of the latitude of the star.

From what has been advanced in relation to the stars on this subject, it will not be difficult to apply a similar process in the case of the occultations of the planets.

CHAPTER XX.

THE CALENDAR.—JULIAN AND GREGORIAN CALENDARS, ETC.

214. Calendar. A register, fixing the dates of important occurrences, and noting the lapse of time by periods, years, months, weeks, days, hours, minutes, and seconds, is called the *Calendar*. The true solar or tropical year contains 365*d*. 5*h*. 48*m*. 48*s*. (26), and since it is most convenient for the common purposes of life, that the civil year should contain a certain number of *whole* days, it has been an object of the greatest importance to invent a scheme by which in all future time, these years may keep pace together.

The nations of ancient times had different calendars, none of which was well arranged for fixing the seasons of the year with any degree of precision. Julius Cæsar, having attained considerable accuracy on this subject, reformed the calendar, by establishing one more simple and less erroneous, than any which had obtained previous to his time.

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214. What is a calendar? What is an object of great importance? What is said of the calendars of ancient times? Who established one more simple and less erroneous, than any previous to his time?

215. Julian Calendar. Julius Cæsar supposed the year to consist of 365*d*. 6*h*., and according to this assumption, made the civil year to contain 365 days for three years in succession, and to allow for the 6 hours, every fourth 366 days. In every fourth year he reckoned the 23d of February twice, which was called *Bis sextus dies*, because the sixth of the calends of March, and thence this year was called *Bissextile*, and the day added, the *Intercalary* day. This year is now frequently called *Leap* year, and *we* add the intercalary day to the end of February. According to this method of reckoning, called the *Julian Calendar*, and dating from the epoch of the Christian era, every year that is divisible by 4 without a remainder, is a leap year, and the others common years.

Now since the Julian year exceeds the true or astronomical year by 11*m*. 12*s*., it would follow that the times of the equinoxes or solstices would occur this much earlier every year, and for instance, the vernal equinox instead of happening on the 20th of March, would happen, after a sufficient lapse of years, on a day previous to that date. Hence, in order hereafter to preserve the commencement of the same seasons, on the same months and the same days of the months, the Julian correction itself needs correction.

216. Gregorian Calendar. The error of the Julian calendar amounts to one day in about 129 years, or 10 days in 1290 years. Pope Gregory XIII., was the first to correct this error. At the time of the Council of Nice, which was held A. D. 325, the vernal equinox happened on the 21st of March, and Gregory, in the year

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215. Explain the Julian calendar. In every fourth year, what day did he reckon twice? What was that year called? What the day added? What is this year now frequently called? What day do we add in leap year? How is it ascertained what years are, and what are not leap years? How much does the Julian year exceed the true year? What follows from this? Why does the Julian correction itself need correction?

216. Who first corrected the Julian error, and in what year? On what day did the vernal equinox happen, at the time of the Council of Nice?

1582, or 1257 years after the Council of Nice, being desirous that it should occur on or near the same day, ordered 10 days, nearly the accumulation of error at this time, to be suppressed in that year, by reckoning the day following the 4th of October, to be called instead of the 5th, the 15th. Thus the calendar was reformed, and in order to correct it for the time to come, it was agreed that three intercalary days should be omitted every 400 years; or, that those centurial years as 1700, 1800, 1900, not divisible by 400, though according to the Julian calendar bissextiles, are to be counted common years, but the centurial year 2000, and others divisible by 400, are still to be considered leap years.

The degree of accuracy according to this mode of reckoning, called the *Gregorian Calendar*, is easily found. The Julian error in one year is 11*m.* 12*s.*, and 11*m.* 12*s.* × 400 = 3*d.* 2*h.* 40*m.* in 400 years; hence, by omitting 3 days, 2*h.* 40*m.* : 1*d.* : : 400*y.* : 3600 years, the time required to produce an error of one day.

217. Adoption of the Gregorian Calendar. In England and her colonies, the Gregorian calendar was not adopted till the year 1752, when the error amounted to 11 days. It was therefore enacted by Parliament, that the day following the 2d of September of that year, should be called the 14th, instead of the 3d. This brought the English dates and the Gregorian calendar to agree, in consequence of the intercalary day in the latter, in the year 1700, having been omitted. The same act of Parliament also changed the beginning of the year from the 25th of March to the 1st of January. In consequence of the suppression of the intercalary day in the year

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Of what was Pope Gregory desirous? What was the error at this time, and how did he correct it? What was agreed, in order to correct it for the time to come? What will result according to the Gregorian mode of reckoning? Show this by the calculation?

217. When was the Gregorian calendar adopted in England and her colonies? What was the error then? What was enacted by Parliament?

1800, there is now 12 days of difference between the Julian and Gregorian calendars, or the *Old* and *New Styles*, as they are now more frequently termed. All Christian countries, except Russia, have adopted the New Style.

CHAPTER XXI.

THE TIDES.

218. REMARKS. The alternate rise and fall of the waters of the ocean, seas, &c., are called the *Tides*, or *flux* and *reflux* of the sea. When the waters approach the shore or are rising, it is called *flood* tide; and when again they recede, it is called *ebb* tide. The determinate limits of the elevation and subsequent depression of the waters at any place, are those of *high* water and *low* water at that place. If the motion of the water is against the wind, it is called a *windward* tide, but if with the wind, it is called a *leeward* tide. The swell in the ocean, called the *primitive* tide-wave, produces tides in the contiguous bays and rivers, called *derivative* tide-waves.

219. CAUSES OF THE TIDES. The action of the sun and moon occasions the tides, particularly that of the

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What is now the difference between the Julian and Gregorian calendars, or the Old and New Styles? What countries have adopted the New Style?

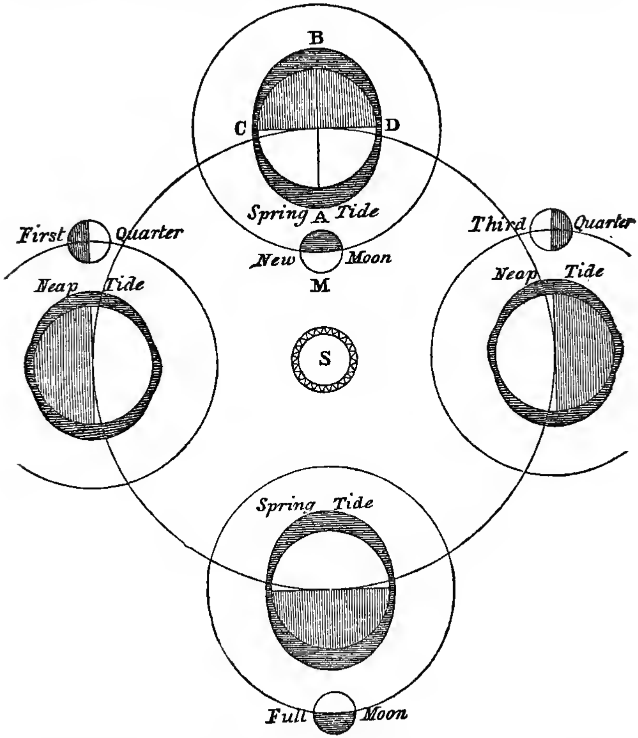
218. What are called the tides? What the flood tide and ebb tide? What is understood by high and low water at any place? What are windward and leeward tides? Describe the primitive and derivative tide-waves?

219. What occasions the tides?

latter body. This power of attraction in a remote body is not the same upon the several particles of the earth, but according to the well established theory of universal gravitation, decreases as the squares of the distances of the particles from the centre of that body, increase; hence the parts of the earth nearest the moon, for example, are more attracted than the lateral and central parts, and these again more than the parts diametrically opposite the former. The parts immediately under the moon are drawn from the earth's centre, and therefore rendered specifically lighter than the lateral parts, which are less drawn and nearly in a horizontal direction: and, the parts opposite to the moon, though they are drawn towards the earth's centre, are also specifically lighter than the lateral parts, which are more drawn and in a direction somewhat towards the earth. Now if the earth were entirely solid, this inequality of the moon's action in attracting the different particles would make no sensible impression on these particles, however situated; but, since a large portion of the external surface is composed of water, which yields to these unequally impressed forces, it is obvious that the waters of the fluid mass nearest and opposite to the moon, must rise, according to the principles of Hydrostatics, and be protruded till by their greater height they balance the waters of the other lateral parts less altered by the inequalities of the moon's action. The greatest depression will evidently be in a great circle 90° distant from the parts nearest and opposite the moon, and if the earth were entirely covered with water, it would assume the figure of an oblong spheroid, having the longest diameter directed towards the moon.

How does this power of attraction in a remote body vary? Hence what? How are the parts immediately under the moon, the lateral, and opposite parts, affected as to their specific gravity, by the inequalities of the moon's action? If the earth were entirely solid, what impression would her unequal action make on the different particles? But since a large portion of the external surface is composed of water, which yields

Thus let M represent the moon, and E the earth, surrounded with water. The waters on the several parts of the hemisphere C A D, nearest the moon, will be darwn from the earth,



by the attractive force which is inversely as the squares of the distances of those parts; hence, the specific gravity of the waters from C and D, where the moon appears in the horizon, to A where she is vertical, will diminish. Again, the waters on the several parts of the opposite hemisphere C B D, will be drawn *towards* the earth by the moon's attractive force, which

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to these unequally impressed forces, what must follow? Where will there be the greatest depression? Fully explain these principles by diminishes as the squares of her distances from those parts increase; hence, also the specific gravity of the waters from C and D to B, the point opposite the moon, will diminish. Therefore it is evident, the fluid mass will form itself into an oblong spheroid, causing high water both at A and B, and low water in the vicinity of the great circle C D, 90° distant from A and B. The elevation of the waters at A and B, or on the sides of the earth nearest and opposite to the moon is nearly equal, because there is nearly an equal diminution of gravity in these positions, on account that the length of the earth's radius is small in comparison to the moon's distance.

The time of high or low water at any place is about 50 minutes later than on the preceding day, because this is the daily variation in the time of the moon's coming to the meridian of any place, and therefore according to the above illustration, it is obvious that in the course of a lunar day, or 24*h*. 50*m*., there will be two floods and two ebbs, which we find to agree with observation.

Similar effects are produced in the waters of the ocean by the action of the sun, but in a less degree; for although his whole attractive force upon the earth is about 166 times that of the moon, yet, as his distance is 400 times as great, the inequality of his action at the different parts is therefore less. The attractive force of the sun in raising the tides, is about one-third that of the moon.

220. Spring and Neap Tides. At the change, the attraction of the sun and moon is nearly in the same line of direction, and therefore united in raising the tides; the force of both bodies is also conjoint, and the effect is very nearly the same at the full, for each raises a tide on the nearest and opposite side of the earth. Hence, at

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referring to the figure. Why is the elevation on the nearest and opposite sides nearly equal? What is the variation in the time of high or low water each day? How many floods and ebbs occur in a lunar day? How many times greater is the whole attractive force of the sun upon the earth, than that of the moon? How then is the inequality of his action at the different parts less? What is the ratio of these forces in raising the tides?

the times of syzygies, the tides run strongei and higher than at other times, and are therefore called *Sp ·ing Tides.* But when the sun and moon differ in longitude 90° or 270°, the influence of the one body counteracts that of the other (see the fig.) ; for the sun then produces low water where the moon produces high water, and the contrary. Hence, at the times of the quadratures, the tides do not rise to their average height, and are therefore called *Neap Tides.* The greatest effects of the sun and moon's action, do not immediately follow that action, but some time after ; hence, the most marked spring and neap tides generally occur about 36 hours after the times of syzygies and quadratures.

Since the attractive forces of the sun and moon in raising the tides, are as 1 to 3, it follows that the effect of these forces, when they act conjointly, is to the effect when they counteract each other, as 4 to 2 ; hence the spring tides rise to a height above the medium surface about double that of the neap tides.

221. PERIGEAN AND APOGEAN TIDES. The influence of the moon on the waters of the ocean, is, as already stated, in the inverse ratio of the quare of her distance ; therefore the greatest tides will occur when she is in perigee, and the least when in apogee. Hence the spring tides that occur soon after the moon passes the perigean point, are unusually high ; and on the contrary, the neap tides that occur soon after she passes the apogean point, are unusually low. These are therefore called the *Perigean* and *Apogean* tides.

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220. When do the tides run stronger and higher, and what then called? Fully explain the cause of these high tides. Refer to the figure. When is it, the tides do not rise to their average height, and what then called? Explain the cause of these low tides. When do the most marked spring and neap tides occur? Why do the spring tides rise to a height double that of the neap tides?

221. Why are the spring tides unusually high soon after the moon passes the perigean point? And why are the neap tides unusually low, after she passes the apogean point? What are these tides called?

A slight change in the tides will also result, on account of the variation of the sun's distance from the earth.

222. Effect of the Moon's Declination on the Tides. When the moon is in the equinoctial, the highest tides will evidently occur along the equator. But when the moon declines from the equinoctial, the opposite elevations will describe opposite parallels, one of which will correspond to her declination. From these parallels the height of the tides will gradually diminish towards the north and south, and therefore, in considerable high latitudes, any two consecutive tides will be of unequal height. At places 90° distant from the greatest elevation, on the opposite side of the equator, the less tide will vanish; and hence, in the polar seas there will be but one small flood and ebb in the course of a lunar day.

In north latitude, when the moon's declination is north, the tide will be higher when she is above the horizon, than when she is below it; but when the declination is south, the reverse will be the case. This irregularity in the tides will be the greatest when the sun and moon have the same and the greatest declination.

223. Motion and Lagging of the Tides. The primitive tide-wave follows the moon in her apparent westerly course round the earth. This is not the continued forward motion of the same portion of water, but the effect of the attractive force on successive portions. Though the moon's action is the greatest on the waters of any place, when she is on the meridian of that place, yet in the open ocean, where the waters flow freely, it will not be high water generally until about two hours after she has pass-

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222. When the moon is in the equinoctial, where will the highest tides occur? When the moon declines from the equinoctial, why will two consecutive tides in considerable high latitudes, be of unequal height? And why, in the polar seas, will there be but one small flood and ebb in the course of a lunar day? When will the irregularity in the tides be the greatest, and why?

223. How long, generally, in the open ocean, after the moon has passed

ed either the superior or inferior meridian. A want of time in the waters to yield to the impulse given by the action of the moon, is the cause of this delay or *Lagging* of the tide-wave. The tide-wave does not always answer to the same distance of the moon from the meridian, but is slightly affected in its motion, caused by the relative positions of the sun and moon.

Although the great tide-wave in the open ocean follows the moon at the distance of about 30° from her, yet the time of high water at places situated on bays, rivers, &c., will occur at all distances of the moon from the meridian, and consequently at all hours of the lunar day. This variation in the time of high water at different places, depends on the distances which the derivative tide-waves have to pass, and the greater or less obstructions to their motions from capes, head-lands, and other irregularities of the coast.

224. Establishment of a Port. The mean interval between noon and the time of high water at any port on the days of new and full moon, is called the *Establishment* of that port. When this has been determined by careful observations, and added to the time of the meridian passage of the moon on any day, given in the Nautical Almanac, the result will be the proximate time of high water for that day. The true time is obtained by applying to the proximate time, the corrections due for the sun and moon's declinations and relative positions. Tables containing these corrections, and the establishment of the port for various places, are generally given in treatises on Navigation.

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the meridian, will it be high water? What is this delay of the tides called? Explain the cause of the delay. Does the tide-wave always answer to the same distance of the moon from the meridian? By what affected? Why does the time of high water at places situated on bays, rivers, &c., occur at all distances of the moon from the meridian?

224. What is understood by the establishment of a port? How is this determined? How is the proximate time of high water obtained? And how the true time?

225. Height of the Tides at Different Places. The difference between high and low water varies at different places, being affected by the shape and position of the land. At the small islands in the Pacific ocean, the average height of the flood above the ebb, is only about 2½ feet. Along the eastern coast of North America, the height of the tides has been thus given: at Charleston, S. C., 6 ft.; at New-York, 5 ft.; at New-Haven, 8 ft.; at Boston, 11 ft.; and at Cumberland, Bay of Fundy, 71 ft. This last is the highest tide in the world, and is attributed to the meeting of the northern and southern tide-waves of the Atlantic, at the mouth of that bay.

The Mediterranean and Baltic seas have very small tides, because in so short a time between flood and ebb, they do not receive or discharge water enough through the narrow straits by which they communicate with the ocean, very sensibly to elevate or depress their surfaces. Lakes and inland seas have no perceptible tides, because their extent is not sufficient to admit of a sensible inequality of gravity in their waters, as the result of the moon's action.

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225. Why does the difference between high and low water at different places, vary? What is the average height of the flood above the ebb, at the small islands in the Pacific Ocean? Give the height of the tides at some of the most prominent places along the eastern coast of North America. What is said of the tide at Cumberland, Bay of Fundy, and to what attributed? Why have the Mediterranean and Baltic seas very small tides? And why have lakes and inland seas no perceptible tides?

ASTRONOMY.—PART II.

CHAPTER I.

PROBLEMS PERFORMED BY THE TERRESTRIAL GLOBE.

PROBLEM I.

Any place being given, to find its latitude, and all those places which have the same latitude.

RULE.

Find the place on the globe, and bring it to that part of the brass meridian which is numbered from the equator towards the poles, the degree above it is its latitude (18)* north or south, according as the place is on the north or south side of the equator. Turn the globe round on its axis, and all places that pass under the degree on the brass meridian, which is the latitude of the given place, are those which have the same latitude.

EXAMPLES.

1. What is the latitude of Constantinople?
Ans. 41° north.
2. Required the latitude of Petersburg?
3. What places have the same, or nearly the same latitude as Philadelphia?
Ans. Pekin, Naples, Constantinople, Madrid, &c.
4. The length of the longest day at Bergen is 19 hours

* Numbers thus enclosed in a parenthesis, refer to articles in part first.

required those places* which have the longest day the same length.

5. What inhabitants of the earth have the same length of days as the inhabitants of Havana?

6. Where are the seasons of the year the same as at Boston?

7. Find the latitudes of the following places, and all those places which have the same latitudes:

Berlin	Madras	Paris	Washington
Hamburgh	Archangel	Mecca	Mexico
Lisbon	Naples	Cairo	Quebec
New-York	Dublin	New-Orleans	Toulon.

8. What is the greatest latitude that a place can have?

PROBLEM II.

Any place being given, to find its longitude, and all those places which have the same longitude.

RULE.

Find the place on the globe and bring it to the brass meridian, the number of degrees on the equator, counting from the first meridian to the brass meridian, is the longitude (18). If the given place lie to the right hand of the first meridian, the longitude is east; if to the left hand, the longitude is west;† and all places under the same edge of the brass meridian, from pole to pole, have the same longitude.

EXAMPLES.

1. What is the longitude of Pondicherry?
Ans. $79\frac{3}{4}°$ east.

2. What places have the same, or nearly the same longitude as Rome?

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* All places in the same latitude have the same length of day and night, and the same seasons of the year, though they may not have the same atmospherical temperature.

† The learner should stand with his face toward the North Pole.

Ans. Leipsic, Tripoli, Wittenburg, &c.

3. When it is nine o'clock in the morning at Washington, what inhabitants* of the earth have the same hour?

4. What inhabitants of the earth have midnight, when it is midnight at London?

5. What inhabitants of the earth have noon, when those of Baltimore have noon?

6. Find the longitudes of the following places, and all those places which have the same longitudes:

New-York	Quito	Nankin	Quebec
New-Orleans	Leghorn	Bombay	Lima
Copenhagen	Palermo	Aberdeen	Stockholm
Archangel	Canton	The Sandwich Islands	Fez.

7. What is the greatest longitude that a place can have?

PROBLEM III.

Any place being given, to find its latitude and longitude.†

RULE.

Bring the given place to that part of the brass meridian, which is numbered from the equator towards the poles; the degree above it is the latitude, and the degree on the equator, cut by the brass meridian, is the longitude.

EXAMPLES.

1. What is the latitude and longitude of Moscow?

Ans. Lat. $55\frac{3}{4}°$ N. Lon. $37\frac{3}{4}°$ E.

2. What is the latitude and longitude of Mexico?

3. Find the latitudes and longitudes of the following places:

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* Those people who inhabit the earth under the same meridian from 66° 32′ north latitude, to 66° 32′ south latitude, have noon at the same time: and whatever be the hour of the day at any particular place, it will be the same hour at every other place situated under the same meridian.

† The first and second problems include this one, which serves only as a repetition of them.

Algiers	Bagdad	Kingston	Oporto
Amsterdam	Cadiz	Vera Cruz	Athens
Aleppo	Botany Bay	Juan Fernandez	Jaffa
Boston	Vienna	Charleston	Panama.

PROBLEM IV.

The latitude and longitude of any place being given, to find that place.

RULE.

Find the given longitude on the equator, and bring it to the brass meridian; then under the given latitude on the brass meridian, you will find the place required.

EXAMPLES.

1. What place has 155½° west longitude, and 19° north latitude?

Ans. The south point of the island O-why-hee.

2. What place has 113¼° east longitude, and 23° north latitude?

Ans. Canton.

3. Find those places which have the following latitudes and longitudes:

LAT.	LON.	LAT.	LON.
60° 24′ N.	5° 18′ E.	6° 9′ S.	106° 53′ E.
22 33 N.	88 17 E.	31 41 N.	81 11 W.
18 57 N.	72 56 E.	55 59 S.	67 16 W.
34 35 S.	58 22 W.	29 2 S.	167 48 E.
39 17 N.	76 39 W.	32 42 N.	79 54 W.

4. Find those places which have no latitude.
5. Find those places which have no longitude.
6. Find that place which has neither latitude nor longitude.
7. Find those places that have the greatest latitude.
8. Find those places which have the greatest longitude.
9. Find those places that have all possible degrees of longitude reckoned from the same meridian.
10. Find those places that have the greatest latitude and longitude.

PROBLEM V.

To find the difference of latitude between any two places.

RULE.

Find the latitudes of both places by (Problem I.), then, if the latitudes be both north or both south, their difference will be the difference of latitude; but, if the latitudes be one north and the other south, their sum will be the difference of latitude.

EXAMPLES.

1. What is the difference of latitude between Glasgow and Boston?

Ans. $13\frac{1}{2}°$.

2. What is the difference of latitude between the Cape of Good Hope and Philadelphia?

Ans. 74°.

3. How many degrees is Cape Horn south of Cape Verd?

4. Where must those places be situated, which have no difference of latitude?

5. What two places on the globe have the greatest difference of latitude?

6. Required the difference of latitude between the following places:

Cape Blanco and Cape Clear.
Martinico and Bermuda.
Porto Bello and New-Orleans.
London and New-York.
Cape Charles and St. Helena.
Paris and Bergen.
Cape Horn and Cape Henry.
Lisbon and Cape Town.
Lahore and Madras.
Caraccas and Quito.
C. Guardafui and Cape Ambro.
Charleston and Halifax.
St. Helena and Cape Farewell.
Pekin and Lima.
Dublin and Baltimore.
Quebec and Mecca.
Cape May and Cape St. Roque.
Madrid and Berlin.
Athens and Berne.
Cape Fear and Cape Cod.

PROBLEM VI.

To find the difference of longitude between any two places

RULE.

Find the longitudes of both places (by Problem II.), then, if the longitudes be both east or both west, their difference will be the difference of longitude; but, if the longitudes be one east and the other west, their sum will be the difference of longitude, if it does not exceed 180°. If their sum exceeds 180°, take it from 360°, and the remainder will be the difference of longitude.

EXAMPLES.

1. What is the difference of longitude between New-York and Oporto?
Ans. 65½°.
2. Find the difference of longitude between Archangel and London.
3. How many degrees is Leghorn east of Baltimore?
4. What is the difference of longitude between Harvey's Island and Siam?
Ans. 100¼°.
5. What is the greatest number of degrees, that one place can be east or west of another?
6. Required the difference of longitude between the following places:

Fez and the Island of Bourbon.	Jeddo and Acapulco.
Cape Cod and Funchal.	Lyons and Rome.
Botany Bay and Gough's Island.	Edinburgh and Vera Cruz.
Washington and Rochelle.	Calcutta and Mexico.
Canton and Cairo.	Ava and Muscat.
Tunis and Morocco.	Naples and Cadiz.
Bristol and Munich.	Genoa and Smyrna.
London and Boston.	Lands End and Cape May.
Pekin and Lima.	Ava and Washington.

PROBLEM VII.

*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 (6) intercepted between them. Therefore, lay the graduated edge of the quadrant of altitude (11) 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 be their distance in degrees, which multiply by 60 for their distance in geographical miles, or by 69 (88) for their distance in statute miles.

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* Though this problem is very simple in theory, yet, when we apply it to practice, the difficulties which arise are insurmountable. When sailing along the trackless ocean, or travelling through unknown deserts, our only guide is the mariner's compass; and unless the two places be situated on the same meridian, or on the equator, we never can take the shortest path, guided by the compass, as measured by the quadrant, or found by spherical trigonometry.

For example: first, let it be required to find the shortest distance between Cape Henry and Cape St. Vincent, situated nearly on the same parallel of latitude, and differing in longitude about 67°. The shortest distance found by spherical trigonometry, is an arc of a great circle containing 52° 18′, = 3138 geographical miles; but if a ship take her departure from Cape St. Vincent, latitude 37° north, and steer due west till her difference of longitude be 67°, which will bring her to Cape Henry, her true distance sailed will be 3210½ geographical miles, making a circuitous course of 72½ geographical miles. Now to conduct a ship on the arc of a great circle intercepted between the above mentioned places, she must be steered through all the different angles, infinite in number, from N. 68° 17 W. to 90°, and from thence through all the same variety of angles, till she arrives where the angle will be 68° 17′, the same as that first, which is impracticable.

Secondly. Let us take another example, in which the two places differ

Or, extend a pair of compasses between the two places, apply that extent to the equator, and it will show how many degrees it contains, which multiply as above for the distance in miles.

If the distance between the two places exceed the length of the quadrant, stretch a thread between them, and mark their distance; apply this distance to the equator, and it will show the number of degrees between the two places.

EXAMPLES.

1. What is the direct distance between St. Helena and St. Salvador?

Ans. 32°, = 1920 geographical miles, or 2203 statute miles.

2. What is the breadth of South America, from Cape St. Roque to Cape Blanco?

3. What is the length of Africa from Cape Bon to the Cape of Good Hope?

4. What is the extent of Africa in statute miles from Cape Verd to Cape Guardafui?

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in latitude: suppose the Island Madeira, latitude 32° 38′ N. longitude, 17° 6′ W. and the Island Trinidad, latitude 10° 45′ N. longitude, 60°.36′ W. The arc of a great circle contained between the two places, truly calculated by spherical trigonometry, will be 45° 31′, = 2731 geographical miles; and, in order that a ship may sail on this circle, she must steer from Madeira, S. 71° 27′ W. and fluctuate in her course till she arrives at Trinidad, where the course will have gradually decreased to S. 54° 12′ W. which, though true in theory, is impracticable. Therefore, the course and distance must be found by middle latitude or Mercator's sailing. The course will be found to be S. 61° 23′ W. and distance on that course, 2741½ geographical miles, making a difference of 10½ geographical miles.

Hence, it is evident that we never can travel or sail on an arc of a great circle, guided by the compass, except on a meridian or on the equator; consequently, if the two places be otherwise situated, the distance between them, and the point of the compass on which a person must sail or travel from the one place to the other, must be found by middle latitude or Mercator's sailing.

5. What is the direct distance between Cape Horn and the Cape of Good Hope?

6. What is the extent of Europe in statute miles from the North Cape to Cape Matapan?

7. What is the shortest distance between Cape Cod and the Island Bermuda?

8. What is the extent of the Atlantic Ocean from Cape Lookout to Cape Finisterre?

9. How many miles is Africa broader than South America, where crossed by the equator?

PROBLEM VIII.

A place being given, to find all those places which are situated at the same distance from it as any other given place.

RULE.

Place the division marked 0 of the quadrant of altitude on the first given place, and the graduated edge over the other, then observe the degree on the quadrant 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, are those required.

Or, take the distance between the two places in a pair of compasses, and with the first place as a centre, describe a circle; then all places situated in the circumference of this circle, are those required.

When the distance between the two places exceeds the length of the quadrant, or the extent of the compasses, stretch a thread between them, and mark their distance, with which proceed as with the quadrant.

EXAMPLES.

1. What places are situated at the same distance from London as Warsaw is?

Ans. Alicant, Buda, Koningsburg, &c.

2. What places are at the same distance from Moscow as Stockholm is?

3. What islands are situated at the same distance from the Canary Islands as Cape Verde Islands are?

4. What places are situated at the same distance from New York as Madras is?

PROBLEM IX.

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 miles, reduce them to degrees, by dividing by 60 for geographical miles, or by 69 for statute miles; then place 0 of the quadrant of altitude on 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 on the quadrant and parallel of latitude intersect; under the point of intersection you will find the place required.

EXAMPLES.

1. A place in latitude 13° N. is 4209 statute miles from London, and is situated in west longitude; required the place?

Ans. 4209 statute miles = 61°; then 0 of the quadrant placed on London, the 61st degree of the quadrant will intersect the parallel of 13° N. in west longitude, over the island of Barbadoes, the place required.

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* It is necessary to mention whether the place sought lie to the east or west of the given place, because the degrees of distance on the quadrant will cut the parallel of latitude in two points, namely, one east of the given place, and the other west of it.

2. What place east of Bermuda, and latitude 16° S. is 4410 geographical miles from it?

3. A place in latitude 51½° N. and east of Philadelphia, is 3120 geographical miles from it; required the place?

4. Petersburg is 1740 geographical miles distant from two places situated on the parallel of 40° N.; required the two places?

PROBLEM X.

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 miles, reduce them to degrees, as in the preceding problem; then, place that part 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 on the quadrant, and the given meridian of longitude intersect; under the point of intersection you will find the place required.

EXAMPLES.

1. A place in 75° west longitude, and situated south of Dublin, is 2820 geographical miles from it; required the place?

Ans. 2820 geographical miles = 47°; then, 0 of the quadrant placed on Dublin, the 47th degree of the quadrant will intersect the meridian of 75° W. south of Dublin, over Philadelphia, the place required.

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* It is necessary to mention whether the place sought lie to the north or south of the given place, because the degrees of distance on the quadrant may cut the given longitude in two points, namely, the one northward of the given place, and the other southward of it.

2. What place north of Madrid, and longitude 30° east, is 2001 statute miles from it?

3. What place south of Washington, and longitude 16½° W. is 3060 geographical miles from it?

4. A place in 64½° west longitude, and situated south of Lisbon, is 3036 statute miles from it; required the place?

PROBLEM XI.

To find the bearing of one place from another.

RULE.

If both 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.

If the globe have no rhumb-lines* drawn on it, apply the centre of a small compass (8) to any given place, so that the north and south points thereof may coincide with some meridian; the other points of the compass will show the bearing of nearly all the circumjacent places.

EXAMPLES.

1. Required the bearing between Cape Hatteras and the island of Porto Rico?

Ans. S. S. E. ¼ E.

2. On what point of the compass must a ship steer from Cape Sable to Bermuda?

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* There are no rhumb-lines drawn on either Cary's or Bardin's globes

3. Required the bearing between the Lizard and the island of St. Mary, one of the Western Islands?

4. Which way must a ship steer from Ascension Island to St. Helena?

5. Required the bearing between Washington and the following places?

Philadelphia	Albany	Savannah	New-Orleans
Boston	Pittsburg	Nashville	Charleston
St. Augustine	Vincennes	Natchez	New-York.

PROBLEM XII.

To find the angle of position between two places.*

RULE.

Bring one of the places to the brass meridian, and observe its latitude; elevate the north or south pole, according as the latitude is north or south, so many degrees above the horizon as are equal to that latitude; screw

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* Some imagine that the angle of position represents the true bearing of one place from another, while others contend, that the one is very different from the other. Let us endeavor to examine both more minutely, and thence draw the conclusion.

By attending to the rule for finding the angle of position, as laid down in this problem, we shall find that, that part of the quadrant of altitude, intercepted between the two places, always forms the base of a spherical triangle, and the complements of the latitudes of the two places, the two sides; also, that the difference of longitude is the vertical angle. The angles at the base of this triangle are the angles of position between the two places.

1. Let two places be situated in the same latitude, suppose 37° north, and differing in longitude 67°, which will nearly correspond with Cape Henry and Cape St. Vincent. Now conceive a triangle on the globe formed by the co-latitudes of the two places, and that part of the quadrant of altitude between them. In this triangle, we have two sides and the included angle given, to find the base, and the angles at the base; the angles will be found to be each 68° 17′, the triangle being isosceles, and the base 52° 18′. Now if an indefinite number of points be assumed

the quadrant of altitude upon the brass meridian over that place, and move the quadrant till its graduated edge comes over the other place; then the number of degrees on the wooden horizon, between the graduated edge of the quadrant and the brass meridian, counting towards the elevated pole, will be the angle of position (19) between the two places.

EXAMPLES.

1. What is the angle of position between Philadelphia and Paris?

Ans. 52° from the north towards the east.

2. What is the angle of position between Paris and Philadelphia?

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along the base, the angle of position between Cape St. Vincent and each of these points will be N. 68° 17′ W., but were it possible for a ship to sail along this arc, (see the note to Problem VII.) by the compass, she must fluctuate in her course from N. 68° 17′ W. to 90 degrees, and from thence continue sailing through the same variety of angles, till her course becomes 68° 17′; but for a ship to sail from Cape St. Vincent N. 68° 17′ W. she would never arrive at Cape Henry, because her true course by the mariner's compass from Cape St. Vincent, along the parallel of 37° north, to Cape Henry, is invariably west.

2. Let two places be taken, differing in latitudes and longitudes; suppose the island of Madeira, latitude 32° 38′ N. longitude 17° 6′ W. and the island of Trinidad, latitude 10° 45′ N., longitude 60° 36′ W. The angle of position between M. and T. calculated by spherical trigonometry, is S. 71° 27′ W. and the angle of position between T. and M. is, N. 54° 21′ E. Now if we assume any number of points on the arc of a great circle between the two places, the angle of position between M. and each of those points will be invariably 71° 27′; whereas, the angle of position between each point (beginning with that next to M.) and M. is continually decreasing, till it becomes 54° 21′; but the direct course from M. to T. (found by Mercator's sailing,) is S. 61° 23′ W. and from T. to M., N. 61° 23′ E. Therefore, if a ship were to sail from M., S. 71° 27′ W. by the compass, she would never arrive at T., and were she to sail from T., N. 54° 21′ E., she would never arrive at M.

3. What is the angle of position between Washington and Rome?

4. What is the angle of position between New-York and Naples?

5. What is the angle of position between London and Archangel?

6. Required the angles of position between Washington and the following places?

Mexico	Porto Bello	Gottenburg	Lisbon
Lima	St. Domingo	Glasgow	Warsaw
Buenos Ayres	Quito	Algiers	Athens.

PROBLEM XIII.

To find the Antœci, Periœci, and Antipodes of any place.

RULE.

For the Antœci. Bring the given place to the brass meridian, and observe its latitude, then under the same degree of latitude, in the opposite hemisphere you will find the (29) Antœci.

For the Periœci. Bring the given place to the brass meridian, and observe its latitude, set the index of the hour circle to 12, turn the globe half round, or until the index points to the other 12; then under that degree on the brass meridian, which is the latitude of the given place, you will find the Periœci.

Corollary 1. If the two places be on the equator, the angle of position between each place and all the assumed points between it and the other, will be 90°, as also between each point and each place, the same as the bearing by the compass.

Corollary 2. When the two places are situated on the same meridian, the angle of position becomes the bearing.

Hence, the angle of position between two places cannot represent their true bearing by the compass, except those places be situated on the equator, or on the same meridian.

For the Antipodes. Bring the given place to the brass meridian and observe its latitude, set the index of the hour circle to 12, turn the globe half way 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 of the island of Bermuda.

Ans. A place situated a little N. W. of Buenos Ayres, is the Antœci; a place in China, N. W. of Nankin, is the Periœci; and the Antipodes is the S. W. part of New Holland.

2. Required the Antœci, Periœci, and Antipodes of Washington.

3. Required the Antœci of Charleston.

4. Required the Periœci of Philadelphia.

5. What inhabitants of the earth walk diametrically opposite to those of Madrid?

6. A ship in latitude 40° S. and longitude 105° E., required her Antipodes?

7. What places have no Antœci, and their Periœci their Antipodes?

8. What places have no Periœci, and their Antœci their Antipodes?

PROBLEM XIV.

To find how many miles make a degree of longitude in any given parallel of latitude.

RULE.*

Lay the quadrant of altitude parallel to the equator in the given latitude between any two meridians, which dif-

* The reasons of this rule will appear evident from the following properties.

The distance between any two meridians on the equator, is to the distance between the same meridians on any parallel of latitude, as the number of miles contained in one degree of the equator is to the number of miles contained in one degree of that parallel of latitude; but the distance on the equator between those meridians, is to the distance on the fer in longitude 15°;* multiply the number of degrees intercepted between them by 4, and the product will give the length of a degree in geographical miles, which multiply by 1.15 for statute miles.

EXAMPLES.

1. How many geographical and statute miles make a degree of longitude in the latitude of Constantinople?

Ans. 45⅓ geographical miles, and 52 statute miles.

2. How many miles make a degree of longitude in the latitude of Washington?

3. Answer the same question as the preceding, with respect to the following places:

London	Mecca	Fez	Upsal
Edinburgh	Dublin	Tripoli	New-York
Paris	Quebec	Surinam	Petersburgh.

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parallel of latitude between the same meridians, as the number of degrees in that distance, is to the number of degrees of equal length in the other; therefore the number of degrees on the equator between any two meridians, is to the number of degrees of equal length between the same meridians in any parallel of latitude, as the number of geographical miles in one degree of the equator, is to the number of geographical miles in one degree of that parallel of latitude.

Thus, in the latitude of 40°, the distance between two meridians which differ in longitude 15°, measured by the quadrant of altitude, is 11½° nearly. Then from what has been demonstrated, 15° : 11½° : : 60m. : 46m.; likewise alternately and considering the numbers abstractly 15 : 60 : : 11½ : 46; but 15 : 60 : : 1 : 4; therefore 1 : 4 : : 11½ : 46; hence, 11½ × 4 = 46 × 1 = 46, the number of geographical miles contained in one degree of longitude in the latitude of 40°. And the number of geographical miles multiplied by 1.15, will give the statute miles, because 60 : 69 : : 1 : 1.15.

When great exactness is required, recourse must be had to calculation, as shown in the note to the table annexed to this problem, because the quadrant of altitude will measure no arc truly but that of a great circle; consequently, the rule cannot be mathematically true, though sufficiently correct for all practical purposes.

* The meridians on some large globes are drawn through every 10°. The rules for such globes will answer by reading 10° for 15°, and by multiplying by 6 instead of 4

A TABLE,

*Showing how many miles make a degree of longitude, in every degree of latitude.**

Deg. Lat.	Geo. Miles.	Statute Miles.	Deg. Lat.	Geo. Miles.	Statute Miles.	Deg. Lat.	Geo. Miles.	Statute Miles.
1	59.99	68.99	31	51.43	59.13	61	29.09	33.45
2	59.96	68.95	32	50.88	58.51	62	28.17	32.40
3	59.92	68.91	33	50.32	57.87	63	27.24	31.33
4	59.85	68.83	34	49.74	57.20	64	26.30	30.24
5	59.77	68.74	35	49.15	56.51	65	25.36	29.15
6	59.67	68.62	36	48.54	55.81	66	24.40	28.06
7	59.55	68.48	37	47.92	55.10	67	23.45	26.96
8	59.42	68.33	38	47.28	54.37	68	22.48	25.85
9	59.26	68.15	39	46.63	53.62	69	21.50	24.73
10	59.09	67.95	40	45.96	52.85	70	20.52	23.60
11	58.89	67.72	41	45.28	52.07	71	19.53	22.47
12	58.69	67.49	42	44.59	51.27	72	18.54	21.32
13	58.46	67.23	43	43.88	50.46	73	17.54	20.17
14	58.22	66.95	44	43.16	49.63	74	16.54	19.02
15	57.95	66.64	45	42.43	48.78	75	15.53	17.86
16	57.67	66.32	46	41.68	47.93	76	14.52	16.70
17	57.38	65.99	47	40.92	47.06	77	13.50	15.52
18	57.06	65.62	48	40.15	46.16	78	12.48	14.35
19	56.73	65.24	49	39.36	45.26	79	11.45	13.17
20	56.38	64.84	50	38.57	44.35	80	10.42	11.98
21	56.01	64.41	51	37.76	43.42	81	9.38	10.79
22	55.63	63.97	52	36.94	42.48	82	8.35	9.59
23	55.23	63.51	53	36.11	41.53	83	7.31	8.41
24	54.81	63.03	54	35.27	40.56	84	6.27	7.21
25	54.38	62.54	55	34.41	39.58	85	5.22	6.00
26	53.93	62.02	56	33.53	38.58	86	4.18	4.81
27	53.46	61.48	57	32.68	37.58	87	3.14	3.61
28	52.97	60.93	58	31.79	36.57	88	2.09	2.41
29	52.48	60.35	59	30.90	35.54	89	1.05	1.21
30	51.96	59.75	60	30.00	34.50	90	0.00	0.00

* The circumferences of circles are to each other as their radii; hence, the earth's semidiameter at the equator, is to the semidiameter of any parallel of latitude, as the circumference of the equator, is to the circum-

PROBLEM XV.

To find at what rate per hour the inhabitants of any 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 Prob. XIV.), which multiply by 15 for the answer.*

EXAMPLES.

1. At what rate per hour are the inhabitants of Philadelphia carried, from west to east, by the revolution of the earth on its axis?

Ans. The latitude of Philadelphia is 40° N., where a degree of longitude measures 46 geographical miles, or 52.8 statute miles. Then $46 \times 15 = 690$, and $52.8 \times 15 = 792$; hence, the inhabitants of Philadelphia are carried 690 geographical miles, or 792 statute miles per hour, by the revolution of the earth on its axis.

2. At what rate per hour are the inhabitants of Petersburgh

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ference of that parallel of latitude, or as the length of one degree on the equator, is to the length of one degree on that parallel of latitude. But the semidiameter of the earth at the equator is the sine of 90°, and the semidiameter of any parallel of latitude, is the cosine of that latitude; therefore as radius is to the cosine of any parallel of latitude, so is 60 geographical miles, the length of a degree on the equator, to the length of a degree in geographical miles, on that parallel of latitude. By the last proportion the table was constructed.

* The reason of this rule is evident, because $360° \div 24 = 15°$, the number of degrees the inhabitants of the earth are carried in one hour; hence the number of miles contained in one degree of longitude on any parallel of latitude multiplied by 15, gives the number of miles the inhabitants are carried round in one hour, on that parallel of latitude.

carried by the revolution of the earth on its axis from west to east?

3. At what rate per hour are the inhabitants of the following places carried by the revolution of the earth on its axis from west to east?

Cairo	Moscow	Buenos Ayres	Washington
Vienna	Bergen	Quito	New-York
Conception	London	Stockholm	Cadiz
Baltimore	Mexico	Lima	Quebec.

PROBLEM XVI.

The hour of the day being given at any place, to find what hour it is at any other place.

RULE.

Bring the place at which the hour is given to the brass meridian, and set the index of the hour circle to 12;* turn the globe on its axis, the nearest way, till the other place comes to the brass 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 at which the hour is given, the hour there is the difference of time later than the given hour; but if it lie to the west, it is the difference of time earlier.

Or, find the difference of longitude in degrees between the two places, (by Prob. VI.), which reduce to time by dividing by 15† for hours, and the remainder, if any, multiply by 4 for minutes. The difference of longitude in time, will be the difference of time between the two places, with which proceed as above.

Note.—The rules given by some authors for the solu-

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* It matters not what hour the index is set to, but 12 is the most convenient. On some globes the brass meridian serves as an index.

† Because $360° \div 24 = 15°$; therefore 15° difference of longitude is equal to one hour, and consequently one degree is equal to four minutes of time.

tion of problems, requiring the use of the hour circle, are not general, but only answer for some particular hour circle. This rule and all succeeding ones are general, and they will answer any hour circle whatever.

EXAMPLES.

1. When it is nine o'clock in the morning at Philadelphia, what hour is it at London?

Ans. The difference of time between the two places will be found to be 5 hours; and because London lies to the east of Philadelphia, it is 5 hours, the difference of time later there; that is, it is two o'clock at London in the afternoon. Or, the difference of longitude between the two places is 75° 11′, which, divided by 15, gives 5 hours 44 seconds, the difference of time; and since London lies to the east of Philadelphia, the clocks there are 5*h.* 44*s.* faster than those at Philadelphia; hence, when it is nine o'clock at Philadelphia in the morning, it is 44 seconds past two in the afternoon at London.

2. When it is eleven o'clock in the morning at Lisbon, what is the hour at Washington?

3. When it is midnight at Mexico, what hour is it at Canton?

4. When it is one o'clock in the morning at Madras, what hour of the day is it at Baltimore?

5. How much are the clocks at New York slower than those at Constantinople?

6. Whether are the clocks of Buenos Ayres faster or slower than those of Baltimore, and how much?

Ans. The clocks of Buenos Ayres are 1*h.* 13*m.* faster than those of Baltimore.

7. When it is half past ten o'clock in the afternoon at Charleston, what is the hour at Madrid?

8. My watch being well regulated when I left Amsterdam, but when I arrived at Havana, it was 5 hours and 40 minutes faster than the clocks there. How much did it gain or lose during the voyage?

Ans. It lost 9 minutes.

9. When the sun wants 3 hours and 15 minutes of coming to the meridian of Boston, what time has elapsed since he came to the meridian of Paris on that day?

PROBLEM XVII.

The hour of the day being given at any place, to find all those places on the globe where it is any other given hour.

RULE.

Bring the given place to the brass meridian, and set the index of the hour circle to 12; then, if the hour at the required places be earlier than the hour at the given place, turn the globe on its axis eastward, till the index has passed over as many hours as are equal to the difference of time between the hour at the given place, and the hour at the required places; but if the hour at the required places be later than the hour at the given place, turn the globe westward on its axis, till the index has passed over as many hours as are equal to the same difference of time, and in each case, all the places required will be found under the brass meridian.

Or, reduce the difference of time between the hour at the given place and the hour at the required places into degrees, by allowing 15° to an hour. The difference of time in degrees, will be the difference of longitude between the given place and the required places; then 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; but 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.*

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* A thorough understanding of this problem and all others of a like nature, depends on a correct idea of the rotation of the earth on its axis, from west to east. Let us conceive the sun fixed at an immense distance from the earth and over the meridian of Baltimore; now, when the sun

EXAMPLES.

1. When it is nine o'clock at Philadelphia in the morning, at what places is it half past four in the afternoon?

Ans. The difference of time between nine o'clock in the morning and half past four in the afternoon, is $7\frac{1}{2}$ hours, and the time at the required places is later than at Philadelphia, the given place; therefore they must lie to the eastward of it. Bring Philadelphia to the brass meridian, and set the index of the hour circle to 12, then by turning the globe westward till the index has passed over $7\frac{1}{2}$ hours, you bring those places to the brass meridian, which lie eastward of Philadelphia, and have the hour of the day $7\frac{1}{2}$ hours later than at Philadelphia. All the places of note under the meridian are Moscow, Aleppo, &c.

Or, the difference of the time between Philadelphia and the required places, is 7 hours 30 minutes, which multiplied by 15 produces 112° 30′, the difference of longitude between Phila-

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was over the meridian of any other place situated 15° eastward of Baltimore, the earth must have turned on its axis eastward 15°, or the twenty-fourth part of one rotation, equal to one hour of time, to bring him to the meridian of Baltimore; consequently, when it is noon at Baltimore, it is one hour past noon, or one o'clock at all places situated 15° eastward of Baltimore, and at all places 30° eastward it is two o'clock, &c. Also, when the sun is over the meridian of those places situated 15° westward of Baltimore, the earth must have turned on its axis 15° eastward, equal to one hour of time, to bring him there, since he was over the meridian of Baltimore; consequently, when it is noon at Baltimore, it wants one hour to noon at all places situated 15° westward of it, or when it is twelve o'clock at Baltimore, it is eleven o'clock at all places situated 15° westward of it, and ten o'clock at those places situated 30° westward of it, &c. Hence, the following observations are evident.

If a ship sail from any port eastward round the earth till she arrives at the same port again, the people of that ship will reckon one entire day more than those of the port; but if she sail westward, they will reckon one less. Therefore, if two ships sail from the same port, the one eastward and the other westward, till they arrive again at the place from which they departed, their dates will differ two days, the one having gained and the other lost a day.

delphia and the required places; and, since the hour at the required places is later than the hour at Philadelphia, the given place, they must lie 112° 30′ to the eastward of it. Hence, all places situated 112° 30′ eastward of Philadelphia, are those required, and they will be found to be Moscow, Aleppo, &c.

2. When it wants 7 minutes to one o'clock in the afternoon at Paris, where does it want a quarter to 9 o'clock in the morning?

Ans. The difference of time between Paris and the required places, is 4 hours and 8 minutes, and the time at the required places is earlier than that at Paris; therefore, the required places lie 4 hours 8 minutes westward of Paris. Bring Paris to the brass meridian, and set the index to 12, turn the globe on its axis eastward, because the required places lie to the westward of the given place, till the index has passed over 4 hours 8 minutes,* the difference of time; then all places under the brass meridian are those required, and they will be found to be Barbadoes, Falkland Islands, &c.

3. When it wants a quarter to nine o'clock in the morning at Constantinople, where is it noon?

4. When the sun comes to the meridian of Greenwich, where it is but 20 minutes past five o'clock in the morning?

Ans. Mexico.

5. When it is a quarter past noon at London, what inhabitants of the earth have midnight?

6. When it is 20 minutes past noon at Dublin, where is it two o'clock in the afternoon?

7. A ship in 45° north latitude, and the mariners having lost all reckoning with respect to longitude, but from a correct celestial observation found it half past 10 o'clock in the morning, when it was but a quarter past nine by a chronometer, which shows the hour at Philadelphia. Required the longitude of the ship.

Ans. 56° 26′ W.

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* If the hour circle be not divided into parts less than a quarter of an hour, turn the globe eastward till the index has passed over 4 hours; then by turning it two degrees more to the east (reckoning on the equator) answering to 8 minutes of time, you will have the solution very exact. Or, for any number of minutes which cannot be reckoned on the hour circle, turn the globe as many degrees as will correspond with that number of minutes.

8. The clocks of a certain city in the western continent, are 5 hours 8 minutes slower than the clocks of London; required that city.

PROBLEM XVIII.

To find the sun's longitude, or his place in the ecliptic, and his declination, for any given day.

RULE.

Find the given day in the circle of months on the horizon, (8) 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 globe; bring the degree thus found to that part of the brass meridian which is numbered from the equator towards the poles, the degree above it on the brass meridian is the sun's declination north or south, according as it is on the north or south side of the equator.

Or, by the *Analemma.** 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, the degree above it on the brass meridian is the sun's declination. Bring that part † of the ecliptic which cor-

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* The analemma on the globe is a narrow strip painted on some vacant part of it, from the tropic of Cancer to the tropic of Capricorn. It is divided into two parts, by a straight line drawn through the middle from one end to the other. The right hand part commences at the winter solstice, or December 21st, and is divided into months and days of the months, towards the summer solstice, or June 21st, correspondent to the sun's declination for every day in that half of the year. The left hand part commences at the summer solstice, and is divided similarly to the right hand part, towards the winter solstice. On Cary's globes the analemma resembles the figure 8, having been drawn in this shape for the convenience of showing the equation of time.

† If the sun's declination be north, and increasing, the sun's longitude

responds with the day of the month, to the brass meridian, and observe, what degree of it passes under the degree of the sun's declination; that degree of the ecliptic will be the sun's longitude, or place in the ecliptic, for the given day.

EXAMPLES.

1. What is the sun's longitude and declination on the 10th of May?

Ans. The sun's longitude is 20° in ♉, declination 17¾° N.

The earth's place, as seen from the sun, among the fixed stars, is always in the sign and degree opposite the sun's place. Thus, when the sun is 20° in ♉, the earth is 20° in ♏.

2. Required the earth's place, as seen from the sun, on the 30th of October?

The sun's place being given, the day of the month corresponding may be found on the horizon, in the circle of months opposite the given sign and degree.

3. On what day of the month does the sun enter each of the signs?

4. Required the sun's place in the ecliptic and his declination on the 11th of October?

5. Required the sun's longitude and his declination on the following days?

January 14,	April 30,	July 31,	October 8,
February 26,	May 7,	August 28,	November 19,
March 18,	June 10,	September 2,	December 30.

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will be somewhere between Aries and Cancer, and that part of the ecliptic must be brought to the brass meridian; but if 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; but if decreasing, the longitude will be between Capricorn and Aries.

TABLE OF THE SUN'S DECLINATION

FOR 1846.

Days of the month.	JANUARY.	FEBRUARY.	MARCH.	APRIL.	MAY.	JUNE.
1	23° 1′s	17° 7′s	7° 36′s	4° 30′N	15° 3′N	22° 3′N
2	22 56	16 50	7 14	4 54	15 21	22 11
3	22 50	16 32	6 51	5 17	15 39	22 18
4	22 44	16 14	6 28	5 39	15 56	22 26
5	22 38	15 55	6 5	6 2	16 13	22 33
6	22 31	15 38	5 41	6 25	16 30	22 39
7	22 23	15 19	5 18	6 48	16 47	22 45
8	22 15	15 0	4 55	7 10	17 4	22 51
9	22 7	14 41	4 31	7 32	17 20	22 56
10	21 58	14 22	4 8	7 55	17 36	23 1
11	21 49	14 2	3 44	8 17	17 51	23 5
12	21 39	13 43	3 21	8 39	18 6	23 9
13	21 29	13 22	2 57	9 1	18 21	23 13
14	21 19	13 2	2 34	9 22	18 36	23 16
15	21 8	12 42	2 10	9 44	18 50	23 19
16	20 57	12 21	1 46	10 5	19 5	23 22
17	20 45	12 0	1 23	10 26	19 18	23 24
18	20 33	11 39	59	10 47	19 32	23 25
19	20 21	11 18	35	11 8	19 45	23 26
20	20 8	11 56	11	11 29	19 57	23 27
21	19 55	10 35	12 N	11 49	20 10	23 28
22	19 41	10 13	36	12 10	20 22	23 27
23	19 27	9 51	1 0	12 30	20 34	23 27
24	19 13	9 29	1 23	12 50	20 45	23 26
25	18 58	9 7	1 47	13 9	20 56	23 25
26	18 44	8 44	2 10	13 29	21 7	23 23
27	18 28	8 22	2 34	13 48	21 17	23 21
28	18 13	7 59	2 57	14 7	21 27	23 18
29	17 57		3 21	14 26	21 36	23 15
30	17 40		3 44	14 44	21 46	23 11
31	17 24		4 7		21 54	23 7

TABLE OF THE SUN'S DECLINATION

FOR 1846.

Days of the month.	JULY.	AUGUST.	SEPT.	OCTOBER.	NOVEMBER.	DECEMBER.
1	23° 8′N	18° 4′N	8° 20′N	3° 8′S	14° 25′S	21° 49′S
2	23 4	17 49	7 59	3 32	14 44	21 58
3	23 0	17 34	7 37	3 55	15 3	22 7
4	22 55	17 18	7 15	4 18	15 21	22 15
5	22 49	17 2	6 52	4 41	15 40	22 23
6	22 43	16 46	6 30	5 4	15 58	22 30
7	22 37	16 29	6 8	5 28	16 16	22 37
8	22 31	16 12	5 45	5 51	16 34	22 44
9	22 24	15 55	5 23	6 13	16 51	22 50
10	22 16	15 38	5 00	6 36	17 8	22 55
11	22 9	15 20	4 37	6 59	17 25	23 1
12	22 1	15 2	4 14	7 22	17 41	23 5
13	21 52	14 44	3 51	7 44	17 57	23 10
14	21 43	14 25	3 28	8 7	18 13	23 14
15	21 34	14 7	3 5	8 29	18 29	23 17
16	21 25	13 48	2 42	8 51	18 44	23 20
17	21 15	13 29	2 19	9 13	18 59	23 22
18	21 4	13 10	1 55	9 35	19 13	23 24
19	20 54	12 50	1 32	9 57	19 28	23 26
20	20 43	12 31	1 9	10 29	19 41	23 27
21	20 31	12 11	45	10 40	19 55	23 27
22	20 20	11 51	22	11 1	20 8	23 28
23	20 8	11 30	1 S	11 23	20 21	23 27
24	19 55	11 10	25	11 44	20 33	23 26
25	19 42	10 49	48	12 4	20 45	23 25
26	19 29	10 28	1 12	12 25	20 57	23 23
27	19 16	10 8	1 35	12 46	21 8	23 21
28	19 2	9 46	1 58	13 6	21 19	23 18
29	18 48	9 25	2 22	13 26	21 29	23 15
30	18 34	9 4	2 45	13 46	21 39	23 11
31	18 19	8 42		14 5		23 7

PROBLEM XIX.

To show the comparative lengths of the days and nights at the equinoxes (13), *at the summer solstice, and at the winter solstice.*

1. *For the Equinoxes.* At the time of the equinoxes, the sun has no declination, being at that time in the equinoctial in the heavens, which is an imaginary line standing vertically over the equator on the earth (7); therefore, place the two poles of the globe in the horizon, and suppose the sun to be fixed at a considerable distance from the globe, in that part of the equinoctial in the heavens, which stands vertically over that part of the brass meridian which is marked 0. Now 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.

If you bring any place to the western edge of the horizon, the meridian passing through that place, will coincide with the western semicircle of the horizon, and the sun will appear to be rising in the east to all places situated on that meridian; and to all places situated on the opposite meridian, which coincides with the eastern semicircle of the horizon, he will appear to be setting in the west; turn the globe gently on its axis towards the east, and to the different places which successively enter the enlightened hemisphere, the sun will appear to be rising, and to those which enter the dark hemisphere, he will appear to be setting. All the parallels of latitude north and south of the equator, are divided into two equal parts by the horizon; that is, all the diurnal arcs are equal to all the nocturnal arcs (25); therefore it follows, that in turning the globe once round on its axis from west to east, every place on its surface will be the same length of time in the enlightened hemisphere as in the dark hemisphere; consequently, at the time of the equinoxes, the days and nights are equal, or twelve hours each all over the world.

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° above the north point of the horizon, bring the beginning of Cancer in the ecliptic to the brass meridian, and over that degree of the brass meridian, under which the beginning of Cancer stands, suppose the sun to be fixed at a considerable distance from the globe. While the globe remains in this position, the horizon will show the boundary of light and darkness, and to all places in the western semicircle of the horizon, the sun will appear to be rising; and to all places in the eastern semicircle of the horizon, he will appear to be setting.

The planes of all the parallels of latitude are parallel to one another, because each of them is parallel to the plane of the equator, and all these planes of circles from the Arctic circle to the Antartic circle (14), will be cut obliquely by the plane of the horizon, which touches the Arctic circle and diametrically opposite touches the Antartic circle, so that from the equator northward, as far as the Arctic circle, the diurnal arcs, or those above the horizon, will exceed the nocturnal arcs, or those below the horizon; hence, the length of the day exceeds the length of the night; and 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 Antartic circle. the nocturnal arcs will exceed the diurnal arcs, so that the length of the night exceeds the length of the day; and all the parallels of latitude within the Antartic circle will be wholly below the horizon; therefore, the inhabitants (if any) will have twilight or dark night.

If we take any parallel of latitude north of the equator, and compare it with that parallel of latitude, which is the same distance south of the equator, as it is north, we will find that the diurnal arc of the northern parallel, is equal to the nocturnal arc of the southern parallel, and the nocturnal arc of the northern parallel, equal to the diurnal arc of the southern parallel; consequently, when the inhabitants of north latitude have the longest day, those in south latitude have the longest night; and when the inhabitants of north latitude have the shortest night, those of south latitude have the shortest day. The days at the equator are always 12 hours long, because it is divided into two equal parts by the horizon, making the diurnal arc equal to the nocturnal arc.

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° above the southern point of the horizon, bring the beginning of Capricorn to the brass meridian, and over that degree of the brass meridian under which the beginning of Capricorn stands, suppose the sun to be fixed at a considerable distance from the globe. Now, as at the summer solstice, the horizon will show the boundary of light and darkness, and to all places in the western semicircle of the horizon, the sun will appear to be rising; and to all places in the eastern semicircle of the horizon, he will appear to be setting.

From the equator southward, as far as the Antartic circle, the diurnal arcs will exceed the nocturnal arcs; hence, the length of the day exceeds the length of the night; and, all the parallels of latitude within the Antartic circle, will be wholly above the horizon; consequently, the inhabitants (if any) will have no night. From the equator northward, as far as the Arctic circle, the nocturnal arcs will exceed the diurnal arcs, so that the length of the night exceeds the length of the day; and, all the parallels of latitude within the Arctic circle, will be wholly below the horizon; therefore, the inhabitants will have twilight or dark night. The inhabitants south of the equator will now have their longest day, while those north of the equator will have their shortest day. As at the summer solstice, the days and nights at the equator are equal, being each 12 hours long.

PROBLEM XX.

To illustrate the three positions of the sphere (15), *namely, Right, Parallel, and Oblique.*

1. *For the Right Sphere.* The inhabitants of the equator have a right sphere, the north polar star (2) appearing 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; 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 12 hours, and invisible for the same space of time; and, in the course of a year, an inhabitant upon the equator may see all the stars in the heavens.

When the sun is in the equinoctial, he will be vertical to all the inhabitants on the equator, and his apparent diurnal path from east to west, will be over that line; when the sun has 10° of north declination, his apparent diurnal motion will be nearly along that parallel; and, when he has arrived at the tropic of Cancer, his diurnal path in the heavens will be over that line, and he will be vertical to all the inhabitants on the earth in latitude 23° 28′ north. Now, during this apparent motion of the sun from Aries to Cancer, every place on the earth, from the equator to the tropic of Cancer, will have the sun vertical, when his declination is equal to the latitude of that place; and, during his progress from Cancer to Libra in the ecliptic, he will be vertical to all the same places. In the same manner, the sun will be vertical to all places from the equator to the tropic of Capricorn, during his apparent motion from Libra to Capricorn; and also vertical to all the same places, during his apparent motion from Capricorn to Aries. Hence, the sun is vertical twice every year, to every place on the earth between the tropic of Cancer and the tropic of Capricorn, or to every place in the torrid zone (28). During one half of the year an inhabitant on the equator will see the sun due north at noon, and during the other half due south at noon. The greatest meridian altitude of the sun will be 90°, and the least, 66° 32′. The inhabitants on the equator have a right sphere, because the equator and all the parallels of latitude cut the horizon at right angles, and the horizon divides them into two equal parts, making equal day and night.

2. *For the Parallel Sphere.* The inhabitants of the north pole (if any) have a parallel sphere, the north polar star in the heavens appearing exactly, or very nearly, over their heads. Elevate the north pole 90° above the horizon, then the equator will coincide with the horizon, and all the parallels of latitude will be parallel thereto. When the sun enters Aries, on the 20th of March, he will be seen by an inhabitant of the north pole to skim along the edge of the horizon; and as he increases in declination, he will increase in altitude, the altitude always being equal to the declination. The sun will form a kind of spiral curve from the equator or horizon, till he arrives at the tropic of Cancer, when his greatest declination is 23° 28′ equal to his greatest altitude, after which time 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; consequently, the stars and planets will be invisible during that period. Though the inhabitants of the north pole will lose sight of the sun in a short time after the autumnal equinox, yet the twilight will continue for nearly two months, or till the sun descends 18° below the horizon, after which all the stars in the northern hemisphere will become visible, and appear to have a diurnal revolution round the earth from east to west. The planets, when in any of the northern signs, will be visible.

The inhabitants under the north polar star, will have the moon constantly above their horizon during 14 revolutions of the earth on its axis, because, at every full moon, which happens from the 23d of September to the 20th 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 it, as 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 then 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 most elevated, and Libra the setting point; it follows that 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 during 14 revolutions of the earth on its axis. Thus the north pole is supplied one half of the winter time with constant moon light in the absence of the sun; and the inhabitants only lose sight of the moon from her third quarter to her first, while she gives but little light, and of course can be but of little or no use to them. The inhabitants of the north pole have a parallel sphere, because the equator coincides with the horizon, and all the parallels of latitude are parallel thereto.

3. *For the Oblique Sphere.* 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; and, if the globe be placed north and south by a compass (8), it will have exactly the same position, with respect to the heavens, as our earth has in that latitude; the axis of the globe will be parallel to the axis of the earth, and the north pole of the globe will point to the north polar star in the heavens. On the equator, the north polar star appears in the horizon; in 10° of north latitude it will be 10° above the horizon; in 20° of north latitude it will be 20° above the horizon; and so on, always increasing in altitude as the latitude increases. The plane of the wooden horizon will be parallel to the plane of the rational horizon of that latitude.

The meridian altitude of the sun may be found for any day by counting the number of degrees from the parallel in which the sun is on that day to the horizon, upon the brass meridian. Every inhabitant of the earth has an oblique sphere, except those who live upon the equator, or exactly at the poles, because the horizon cuts the equator obliquely, and has the days and nights of unequal lengths, the parallels of latitude, being divided into unequal parts by the rational horizon.

PROBLEM XXI.

Any day being given, to find all those places of the earth where the sun is vertical, or in the zenith, on that day.*

RULE.

Find the sun's declination (by Prob. XVIII.) for the given day; turn the globe round on its axis from west to east, and all the places on the globe, which pass under the degree of the sun's declination on the brass meridian will have the sun vertical on that day.

Or, *by the Analemma.* Find the given day on the analemma, and bring it to the brass meridian; the degree above it is the sun's declination; with which proceed as above.

EXAMPLES.

1. Find all those places of the earth where the sun is vertical on the 17th of May.

Ans. Mexico, the north part of St. Domingo, O-why-hee Island, Bombay Island, &c.

2. What inhabitants of the earth have the sun vertical on the 25th of October?

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* If it be required to find those places where the moon will be vertical on any given day, find the moon's declination for the given day, in the Nautical Almanac, and observe it on the brass meridian; all places passing under that degree of declination, will have the moon vertical, or nearly so, on the given day.

3. What inhabitants of the earth have no shadow at noon, on the 27th of April?

4. What inhabitants of the earth have the sun vertical on the following days?

June 21	March 20	August 31	January 7
September 23	May 11	October 17	February 19
December 21	July 29	November 23	April 30.

5. Find those places of the earth where the moon was vertical, or nearly so, on the 8th of May, 1848, her declination then being 15° 38′ N.

PROBLEM XXII.

The month and day of the month being given, and the hour of the day at any place, to find where the sun is vertical at that instant.

RULE.

Find the sun's declination, (by Prob. XVIII.), 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, till the index has passed over as many hours as it 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 it is past noon; in each case, the place exactly under the degree of the sun's declination on the brass meridian, will be that required.

EXAMPLES.

1. When it is 40 minutes past one o'clock in the afternoon at Philadelphia, on the 17th of May, where is the sun vertical?

Ans. The given time is one hour 40 minutes past noon; hence, the globe must be turned towards the east, till the index has passed over one hour 40 minutes; then, under the sun's declination, you will find Mexico, the place required.

2. When it is 48 minutes past 6 o'clock in the morning at Paris, on the 25th of April, where is the sun vertical?

Ans. The given time is 5 hours 12 minutes before noon; therefore, the globe must be turned towards the west, till the index has passed over 5 hours 12 minutes; then, under the sun's declination, you will find Madras, the place required.

3. When it is 45 minutes past 4 o'clock in the afternoon at Dublin, on the 24th of October, where is the sun vertical?

4. When it is 8 minutes past 4 o'clock in the afternoon at London, on the 15th of April, where is the sun vertical?

5. When it is midnight at Washington on the 26th of March, where is the sun vertical?

6. When it is noon at Baltimore on the 11th of May, where is the sun vertical?

7. When it is 50 minutes past 2 o'clock in the afternoon at London, on the 2d of January, where is the sun vertical?

8. When it is 15 minutes past 5 o'clock in the morning, at Rome, on the 21st of June, what inhabitants of the earth have noon, but no shadow?

9. When it is 47 minutes past 7 o'clock, in the morning, at Washington, on the 13th of October, where is the sun vertical?

10. When it is 2 o'clock in the morning at Washington, on the 26th of May, where is the sun vertical?

PROBLEM XXIII.

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 he is setting, those places that have morning twilight, and those places that have evening twilight.

RULE.

Find the sun's declination (by Prob. XVIII.) 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 12; then, turn the globe eastward or westward, according as the given time is past or before noon, till the index has passed over as many hours as it is past or before noon; screw the quadrant of altitude on the brass meridian over the degree of the sun's declination, and let it pass between the globe and the horizon; keep the globe in this position; then, all places along the western edge of the horizon will have the sun rising; those along the eastern edge will have the sun setting; all places below the western edge of the horizon, within 18°, shown by the quadrant of altitude, will have morning twilight; and, all places below the eastern edge of the horizon, within 18°, shown by the quadrant, will have evening twilight.

EXAMPLES.

1. When it is 30 minutes past 10 o'clock in the morning at Madrid, on the 17th of May, find those places that have the sun rising, those that have the sun setting, those that have morning twilight, and those that have evening twilight.

Ans. The sun is rising at Lexington in Kentucky, Port Royal in Jamaica, Carthagena in Terra Firma, &c. Setting at Batavia in Java, the eastern parts of China, &c. Morning twilight at the western parts of South America, Louisiana, &c. And evening twilight at Japan, Luzon, Borneo, &c.

2. When it is 20 minutes past 8 o'clock in the morning at New-York, on the 28th of December, where is the sun rising, setting, &c.?

3. When it is midnight on the 11th of January at Washington, where is the sun rising, &c.?

4. When it is noon at Baltimore on the 25th of April, where is the sun rising, &c.?

5. When it is 8 o'clock in the afternoon at Naples, on the 21st of June, where is the sun rising, &c.?

6. When it is 15 minutes past 4 o'clock in the afternoon at Petersburg, on the 17th of November, where is the sun rising, &c.?

7. When it is 11 o'clock in the morning at London, on the 23d of September, where is the sun rising, &c.?

8. When it is noon at Washington on the 12th of November, where is the sun rising, &c.?

9. When it is midnight at Paris on the 21st of June, where is the sun rising, &c.

PROBLEM XXIV.

The month and day of the month being given, to find all those places of the earth 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 Prob. XVIII.) 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; turn the globe on its axis from west to east; then, to those places which do not descend below the horizon, near the elevated pole, the sun does not set on the given day;* and to those places near the depressed pole, which do not ascend above the horizon, the sun does not rise on the given day.

EXAMPLES.

1. Find all those places of the earth where the sun does not set, and those where he does not rise, on the 7th of June.

Ans. The sun's declination on the given day is $22\frac{3}{4}°$ North. Elevate the north pole $22\frac{3}{4}°$ above the horizon, turn the globe round, and all places within $22\frac{3}{4}°$ of the north pole, will not descend below the horizon; therefore, the inhabitants of those places will have constant day, or to them the sun does not set (being constantly above their horizon) for several revolutions of the earth on its axis. And, because the north pole is elevated $22\frac{3}{4}°$ above the horizon, the south pole is necessarily depressed $22\frac{3}{4}°$ below the horizon; consequently, to the inhabitants of those places within $22\frac{3}{4}°$ of the south pole (if there be any such

* When the pole is elevated to the sun's declination, the horizon shows the boundary of light and darkness; consequently, to that place which does not descend below the horizon, during one revolution of the earth on its axis, the sun does not set; and the inhabitants will have their shadows directed to every point of the compass in the course of 24 hours.

inhabitants) the sun will not rise for several revolutions of the earth on its axis.

2. Find all those places where the inhabitants have constant day on the 20th of July, and those places to which the sun does not rise.

3. Does the sun shine over the north pole on the 20th of May? And to what inhabitants is he constantly visible for several revolutions of the earth on its axis?

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 13th of June?

5. How far does the sun shine over the south pole on the 4th of January? And what places are in perpetual darkness?

6. Is the sun visible at the North Cape on the 21st of November?

7. How far does the sun shine over the north pole on the 18th of April?

8. Is the sun visible in 75° south latitude on the 20th of May?

PROBLEM XXV.

Any day between the 20th of March and 21st of June, or between the 23d of September and the 21st of December being given, to find those places at which the sun begins to shine constantly without setting, and those places at which he begins to be totally absent.

RULE.

Find the sun's declination by (Prob. XVIII.) count on the brass meridian from the north or south pole, according as the declination is north or south, as many degrees as are equal to the sun's declination, and observe the degree where the reckoning ends; turn the globe round on its axis, and all places passing under that degree, are those at which the sun begins to shine constantly without setting at that time; and all places that pass under the same number of degrees from the opposite pole, are those at which the sun begins to be totally absent.

EXAMPLES.

1. At what places does the sun begin to shine constantly without setting, during several revolutions of the earth on its axis, on the 18th of May; and at what places does he begin to be totally absent on the same day?

Ans. The sun's declination is $19\frac{1}{2}°$ N. hence, at all places in latitude $70\frac{1}{2}°$ N. the sun begins to shine constantly without setting, namely, at Waygate Island, in Davis' Straits, at Fisher's Island, &c., and in latitude $70\frac{1}{2}°$ S. he begins to be totally absent.

2. In what latitude does the sun begin to shine constantly without setting on the 7th of November, and at what places does he begin to be totally absent?

3. In what latitude does the sun begin to shine without setting on the 27th of April, and in what latitude is he beginning to be totally absent?

4. At what place is the sun beginning to be totally absent on the 14th of November?

5. Where does constant day commence on the 16th of April, and in what latitude does constant twilight or darkness begin?

6. At what place does the sun begin to shine without setting on the 3d of June?

PROBLEM XXVI.

Any place in the torrid zone being given, to find on what two days of the year the sun will be vertical at that place.

RULE.

Find the latitude of the given place, (by Prob. I.) turn the globe on its axis, and observe what two points of the ecliptic pass under that degree of latitude on the brass meridian, find 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, and 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 Mexico?

Ans. On the 17th of May, and on the 26th of July.

2. On what two days of the year will the sun be vertical at Lima?

3. On what two days of the year will the sun be vertical at Madras?

4. On what two days of the year will the sun be vertical at the following places?

Cambodia	St. Helena	Caraccas	Carthagena
Bombay I.	St. Matthew's I.	Owyhee	Kingston
Batavia	Gondar	Quito	Domingo.

PROBLEM XXVII.

To find the time of the sun's rising and setting, and the length of the day and night at any place.*

RULE.†

Find the sun's declination (by Prob. XVIII.) and elevate the north or south pole, according as the declina-

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* The length of the longest or shortest day at any place not in the frigid zones, may be found: for the longest day in north latitude is on the 21st of June, and the shortest on the 21st of December: and the longest day in south latitude is on the 21st of December, and the shortest on the 21st of June.

† From the following observations, the reason of these rules is obvious.

1. When the pole is elevated for the sun's declination, the sun is supposed to be fixed, and the earth to move on its axis from west to east: the horizon shows the boundary of light and darkness. Turn the globe on its axis till any place comes to the brass meridian, then at that place

tion is north or south, as 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

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it will be noon; continue the motion of the globe till the same place comes to the eastern edge of the horizon, then at that place the sun will be setting; hence, the number of hours passed over by the index, from the time that that place was at the brass meridian, till it came to the eastern edge of the horizon, is the number of hours elapsed from noon at that place, till sunset at the same place, that is the time of the sun's setting; if the same place be brought to the western edge of the horizon, then at that place the sun will be rising; and in turning the globe round, the index will have passed over as many hours, when that place comes to the brass meridian, as it will pass over from the time that the same place leaves the brass meridian, till it comes to the eastern edge of the horizon; because the arcs of the parallels of latitude above the horizon, are bisected by the brass meridian; hence, the sun rises the same number of hours before noon that he sets after noon; consequently, the time of the sun's setting deducted from 12, gives the time of his rising; and double the time of the sun's setting gives the length of the day. And, since the sun sets the same number of hours after noon that he rises before noon, he must necessarily set the same number of hours before midnight, that he rises after midnight; so that double the time of the sun's rising gives the length of the night.

2. When the pole is elevated for the latitude of the place, the earth is supposed to be fixed and the sun to move round it from east to west. Bring any place to the brass meridian, and elevate the pole for its latitude, then the wooden horizon is the true rational horizon of that place Now, if we suppose the sun to move from east to west along that parallel of latitude which passes through his place in the ecliptic, he will be rising at that place which we brought to the brass meridian, when he enters the eastern edge of the horizon; it will be noon when he arrives at the brass meridian; and he will be setting when he enters the western edge of the horizon. And, because the brass meridian and horizon remain fixed, this supposed motion of the sun can be shown by bringing the sun's place in the ecliptic on the globe, to the eastern edge of the horizon, and turning the globe on its axis towards the west, till his place comes to the brass meridian, and to the western edge of the horizon; therefore, if the sun's place in the ecliptic for any day be brought to the brass meridian, the number of hours passed over by the index, in turning the globe round till

circle to 12; turn the globe eastward till the given place comes to the eastern edge 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 12, and the remainder will be the time of the sun's rising. Double the time of the sun's setting gives the length of the day, and double the time of his rising gives the length of the night.

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 Prob. XVIII.) bring it to the brass meridian, and set the index of the hour circle to 12; turn the globe westward till the sun's place comes to the western edge of the horizon, and the number of hours passed over by the index will be the time of the sun's setting; with which proceed as above.

Or, *by the Analemma.* Elevate the pole for the latitude of the given place, bring the day of the month on the analemma to the brass meridian, and set the index of the hour circle to 12; turn the globe westward till the day of the month on the analemma comes to the western edge of the horizon, and the number of hours passed over by the index, will be the time of the sun's setting, &c.

NOTE.—Of the following four things, namely, the time

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the sun's place comes to the western edge of the horizon, will be the time of the sun's setting on that day at that place for which the globe is rectified.

3. When the pole is elevated for the latitude of the place, and the day of the month on the analemma brought to the brass meridian, the index will pass over as many hours, in turning the globe round, till the day of the month on the analemma comes to the western edge of the horizon, as it will pass over from the time that the sun's place in the ecliptic for that day leaves the brass meridian, till it comes to the western edge of the horizon; because the day of the month on the analemma, and the sun's place in the ecliptic for that day, are at the same distance from the equator, and consequently on the same parallel of latitude.

of the sun's setting, the time of his rising, the length of the day, and the length of the night; any one being given, the others may be easily obtained without the globe.

EXAMPLES.

1. At what time does the sun rise and set at Philadelphia, on the 25th of May, and what is the length of the day and night?

Ans. The sun sets at a quarter past 7, and rises three-quarters past 4; the length of the day is $14\frac{1}{2}$ hours, and the length of the night $9\frac{1}{2}$ hours.

2. At what time does the sun rise and set at Washington, on the 17th of August, and what is the length of the day and night?

3. What is the length of the longest day and shortest night at New-York?

4. What is the length of the longest night and shortest day at New-York?

5. How much longer is the 21st of June at Dublin than at Baltimore?

6. How much longer is the 21st of December at Baltimore than at Dublin?

7. At what time does the sun rise and set at London, on the 27th of January, and what is the length of the day and night?

8. When the sun sets at 45 minutes past 7 at any place, what is the length of the night there?

9. When the sun rises at a quarter past 4 at any place, what is the length of the day there?

10. At what time does the sun rise and set at the North Cape, on the 11th of April?

11. Required the length of the longest day and shortest night at the following places:

Quebec	Charleston	Liverpool	Moscow
Boston	Quito	Belfast	Vienna
Philadelphia	Glasgow	Lisbon	Naples.

12. Required the length of the shortest day and longest night at the following places:

London	Petersburg	Algiers	Bergen
Paris	Owhyhee	Calcutta	Falkland Islands
Cairo	Otaheite	Mecca	Dublin.

PROBLEM XXVIII.

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.

Bring the sun's place in the ecliptic for the given day (found by Prob. XVIII.) to the brass meridian and observe the degree above it; turn the globe round on its axis till some other point of the ecliptic comes under the same degree of the brass meridian; find this point of the ecliptic on the horizon, and directly against it you will find the day of the month required.

Or, any two days of the year, which are the same number of days from the longest or shortest day, are of equal length; therefore, 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, and the contrary.

Or, *by the Analemma*. Find the given day of the month on the analemma, and directly opposite to it you will find the required day of the month.

EXAMPLES.

1. What day of the year is of the same length as the 5th of May?

Ans. The 7th of August.

2. What day of the year is of the same length as the 23d of October?

3. What day of the year is of the same length as the 7th of February?

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* The same may be found for any place in the frigid zones, provided the sun rises and sets at that place on the given day.

4. What day of the year is of the same length as the 18th of August?

5. If the sun set at 12 minutes past 7 o'clock at Washington, on the 25th of May, on what other day of the year will he set at the same hour?

6. If the sun rise at 48 minutes past 6 o'clock at Philadelphia, on the 30th of October, on what other day of the year will he rise at the same hour.

7. If the sun's meridian altitude at London, on the 31st of January, be 20° 53′, on what other day of the year will his meridian altitude be the same?

8. If the sun's meridian altitude at Lima, on the 25th of October, be 90°, on what other day of the year will his meridian altitude be the same?

PROBLEM XXIX.

To find the length of the longest day at any place in the north frigid zone.*

RULE.

Find the complement of the latitude of the given place, by subtracting its latitude from 90°; count as many degrees on the brass meridian from the equator towards the north pole, as are equal to the complement of the latitude, and mark 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 two points of the ecliptic in the circle of signs on the horizon, and exactly opposite to 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, and the day following the 21st of June, is that on which it ends; the number of days be-

* The same may be found for the south frigid zone; but, since that zone is uninhabited, we shall confine our practice entirely to the north frigid zone.

tween these days will show the length of the longest day at the given place.

Or, *by the Analemma.* Count as many degrees on the brass meridian from the equator towards the north pole, as are equal to the complement of the latitude of the given place, and mark where the reckoning ends; bring the analemma to the brass meridian, and the two days which stand under the above mark, will show the beginning and end of the longest day.

EXAMPLES.

1. What is the length of the longest day at the North Cape, in latitude 71° 30′ N.?

Ans. The complement of the latitude is 18° 30′; the longest day will be found to begin on the 14th of May, and end the 30th of July; therefore, the length of the longest day is 77 days, or, the sun does not set during 77 revolutions of the earth on its axis.

2. What is the length of the longest day at Disco Island, in Baffin's Bay, in latitude 70° north?

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?

5. What is the length of the longest day at Melville Island, in latitude 76° north?

PROBLEM XXX.

To find the length of the longest night at any place in the north frigid zone.*

RULE.

Count as many aegrees on the brass meridian from the equator towards the south pole, as are equal to the complement of the latitude of the given place, and mark

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* We may apply this problem to any place in the south frigid zone, were that zone inhabited.

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 opposite to 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, and the day following the 21st of December, is that on which it ends, the number of days between these days will show the length of the longest night at the given place.

Or, *by the Analemma.* Count as many degrees on the brass meridian from the equator towards the south pole, as are equal to the complement of the latitude of the given place, and mark where the reckoning ends; bring the analemma to the brass meridian and the two days which stand under the above mark, will show the beginning and the end of the longest night.

EXAMPLES.

1. What is the length of the longest night at the North Cape, in latitude 71° 30′ north?

Ans. The complement of the latitude is 18° 30′, the longest night begins on the 25th of November, and ends on the 27th of January, making it equal in length to 73 days or revolutions of the earth on its axis.

2. What is the length of the longest night at Nova Zembla, in latitude 74° north?

3. On what day of the year does the sun set without rising for several revolutions of the earth on its axis, at Disco Island, latitude 70° north?

4. What is the length of the longest night at the north pole, and on what days does it begin and end?

5. What is the length of the longest night at Melville Island, in latitude 76° north?

PROBLEM XXXI.

The length of the day being given at any place, 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 of the hour circle to 12; turn the globe eastward on its axis till the index has passed over as many hours as are equal to the half 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 edge of the horizon; the distance of the elevated pole above the horizon will be the sun's declination north or south, according as the north or south pole is elevated; find the degree of 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 that degree: find those points in the circle of signs on the horizon, and exactly opposite to them in the circle of months, stand the days of the months required.

Or elevate the pole for the latitude of the place, bring any meridian on the globe to coincide with the brass meridian, and set the index to 12; turn the globe eastward* till the index has passed over as many hours as are equal to the half length of the day and observe the point where the meridian, which you brought to the brass meridian, is cut by the eastern edge of the horizon; bring this point to the brass meridian, and the degree above it will be the sun's declination, with which proceed as above.

Or, *by the Analemma.* Elevate the pole for the latitude of the place, bring the middle of the analemma to the brass meridian, and set the index of the hour circle

* The globe may be turned eastward or westward; but it will be more convenient to turn it eastward, because the brass meridian is graduated on the east side.

to 12; turn the globe eastward till the index has passed over as many hours as are equal to the half length of the day; observe what point on the line, passing through the middle of the analemma, is cut by the eastern edge of the horizon, and exactly against this point, on either side of the analemma, will be found the day of the month required; bring the analemma to the brass meridian, and the degree above this day will be the sun's declination.

EXAMPLES.

1. What two days of the year are each 14 hours long at Philadelphia, and what is the sun's declination?

Ans. The 7th of May and the 5th of August; the sun's declination is 17° north.

2. What two days of the year are each 15 hours long at London, and what is the sun's declination?

3. On what two days of the year does the sun rise at half past five o'clock at Washington?

4. What day of the year at New York is 15 hours long?

5. What day of the year at the North Cape is one hour long?

6. What night of the year at the North Cape is one hour long?

7. On what two days of the year does the sun rise at four o'clock at Edinburg?

8. On what two days of the year at Petersburg, is the time of the sun's rising double that of his setting; and on what two days is the time of his setting double that of his rising?

PROBLEM XXXII.

The month and day of the month being given, to find those places at which the day is a certain length.

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 index has passed over as many hours as are equal to the half length of the day; keep the globe from revolving on its axis, and elevate or depress one of the poles till the sun's place in the ecliptic comes to the western edge of the horizon; then the elevation of the pole above the horizon will be the latitude north or south, according as the north or south pole is elevated, turn the globe on its axis, and all places passing under that latitude, will be those required.

Or, *by the Analemma.* Bring the day of the month on the analemma to the brass meridian, and proceed as above.

NOTE.—By the above rule all those places not in the frigid zones may be found, at which the longest day is a certain length, by bringing the beginning of Cancer or Capricorn to the brass meridian, according as the longest day is on the 21st of June, or on the 21st of December, and proceeding as above.

EXAMPLES.

1. Find those places at which the 25th of May is $14\frac{1}{2}$ hours long?

Ans. Philadelphia, Pekin, &c.

2. Find those places at which the 20th of November is 14 hours long.

3. At what place does the sun set at 25 minutes past seven o'clock, on the 11th of August?

4. At what place is the 21st of June 19 hours long?

5. At what place is the 21st of December $8\frac{1}{4}$ hours long?

6. At what place is the 21st of June $6\frac{3}{4}$ hours long?

7. At what place is the 21st of December $17\frac{1}{4}$ hours long?

8. In what latitude does the sun set at ten o'clock on the 3d of May?

9. There is a town in Norway, where the longest day is five times the length of the shortest night, what is its name?

10. In what latitude south, is the longest day 17 hours?

PROBLEM XXXIII.

To find in what latitude in the north frigid zone, the longest day is a certain length.*

RULE.†

Count as many days on the horizon from the 21st of June, eastward or westward, as are equal to the half length of the day, and opposite to the last day, observe the sign and degree in the circle of signs; find the same sign and degree in the ecliptic on the globe, which bring to the brass meridian, and observe the degree above it; subtract the same number of degrees from 90°, and the remainder will be the latitude required.

Or, *by the Analemma.* Count as many days on the analemma, from the 21st of June, as are equal to the half length of the day; bring the last day to the brass meridian, and the degree above it deducted from 90°, will give the latitude.

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* The same rule will answer for the south frigid zone, only count from the 21st of December.

† This problem is the reverse of the 29th, and the reason of the rule is easily understood; because the longest day at any place in the north frigid zone, begins as many days before the 21st of June, as it ends after the 21st of June; therefore, the half length of the longest day counted backwards from the 21st of June, will show the beginning of the longest day, or the day on which the sun begins to shine constantly without setting in the required latitude; now the sun's declination being found for this day; and subtracted from 90°, will give the latitude; because when the sun's declination is north, he begins to shine constantly in that parallel of latitude, which is as many degrees from the north pole, as are equal to the declination. The half length of the longest day may be counted from the 21st of June forwards; for the sun's declination is the same as many days after the 21st of June, as it is the same number of days before the 21st of June

EXAMPLES.

1. In what degree of north latitude, and at what place, is the length of the longest day 77 days?

Ans. At the North Cape, in latitude $71\frac{1}{2}°$ north.

2. At what place in the north frigid zone, does the sun shine constantly without setting, during 63 revolutions of the earth on its axis?

3. In what degree of north latitude is the longest day 120 days in length?

NOTE.—If it be required to find in what latitude in the north frigid zone the longest night is a certain length, count as many days on the horizon from 21st of December,* eastward or westward, as are equal to the half length of the night, and proceed as in the above rule.

4. In what latitude, and at what place in the north frigid zone, is the length of the longest night 73 days?

5. In what degree of north latitude is the length of the longest night 96 days?

6. In what degree of north latitude is the sun totally absent during 112 revolutions of the earth on its axis?

PROBLEM XXXIV.

To find the number of days on which the sun rises and sets every year, at any place in the north† frigid zone.

RULE.

Find the length of the longest day (by Prob. XXIX.)

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* The longest night at any place in the north frigid zone, begins as many days before the 21st of December, as it ends after the 21st of December; therefore the half length of the longest night counted backwards from the 21st of December, will show the day on which the longest night begins, or the day on which the sun begins to be totally absent in the required latitude; find the sun's declination for this day and subtract it from 90°, the remainder will be the latitude; because, when the sun's declination is south, he begins to be totally absent in that parallel of latitude, which is as many degrees from the north pole, as are equal to the declination.

† This problem is equally applicable to a place in the south frigid zone.

at the given place, and the length of the longest night (by Prob. XXX.); add these together and subtract their sum from 365 days, the length of the year, the remainder will show the number of days which the sun rises and sets every year at that place.

Or, *by the Analemma.* Count as many degrees upon the brass meridian on both sides of the equator as are equal to the complement of the latitude of the given place, and observe the degrees where the reckoning ends; bring the analemma to the brass meridian, and observe what two days on the right hand side of the analemma stand under the observed degrees on the brass meridian; the time between these days (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 left hand side of the analemma, which stand under the same degrees on the brass meridian, (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; add these numbers together, and the sum will show the number of days on which the sun rises and sets every year at that place.

EXAMPLES.

1. How many days in the year does the sun rise and set at the North Cape, in latitude 71s 30′ north ?

Ans. The length of the longest day found by Prob. XXIX. is, 77 days; and the length of the longest night, found by Prob. XXX. is 73 days; hence, $365 - (77 + 73) = 215$, the number of days on which the sun rises and sets.

Or, *by the Analemma,* you will find the longest night to end on the 27th of January, and the longest day to begin on the 14th of May; the time between these days is 107 days, on which the sun rises and sets; and the longest day will be found to end on the 30th of July, and the longest night to begin on the 15th of November; the time between those days is 108 days, on which the sun rises and sets; consequently, the whole time of the sun's rising and setting in the year is 215 days as above.

2. How many days in the year does the sun rise and set at Disco Island, in Baffin's Bay, latitude 70° north?

3. How many days in the year does the sun rise and set at the northern extremity of Nova Zembla?

4. How many days in the year does the sun rise and set at Greenland, in latitude 75° north?

5. How many days in the year does the sun rise and set at the southern extremity of Melville Island?

PROBLEM XXXV.

The month and day of the month being given at any place, to find what day following is an hour longer or shorter than the given day.

RULE.

Find the sun's declination for the given day, and elevate the pole for that declination; bring the given 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, if the days be increasing in length, but westward if decreasing in length, till the index has passed over half an hour, and raise or depress the pole till the place comes again to the horizon; then, the elevation of the pole in both cases, will show the sun's declination on the required day; turn the globe on its axis, and observe what degree in that part of the ecliptic, corresponding to the given day, passes under this declination, reckoned on the brass meridian towards the elevated pole; find this degree of the ecliptic on the horizon in the circle of signs, and opposite to it in the circle of months, you will find the day required.

Or, elevate the pole for the latitude of the given place, and mark the sun's declination for the given day on any meridian; bring this mark to the western edge of the horizon, and set the index to 12; turn the globe westward or eastward, according as the days are increasing or decreasing in length, till the index has passed over half an hour, and observe what point of the same meridian is cut by the horizon, bring that point to the brass meridian and the degree above it will show, in either case, the sun's declination, when the day is an hour longer or shorter than the given day; hence, the required day is easily obtained.

Or, *by the Analemma.* Proceed as in the above rule, only, use the day of the month on the analemma, instead of the sun's declination marked on any meridian.

NOTE.—The day following the given day may be found, which is any given time longer or shorter than it, provided, at the given place, there is this much difference between the length of the given day, and the length of the longest or shortest day.

EXAMPLES.

1. What day following the 8th of April at Philadelphia is an hour longer?

Ans. The 3d of May.

2. What day following the 2d of July is an hour shorter than it, at New-York?

3. On what day following the 11th of September, is the sun 30 minutes later in rising than on that day, at Baltimore?

4. On what day following the 11th of September, is the sun 30 minutes earlier in rising than on that day, at Buenos Ayres?

5. What day following the 14th of July is 2 hours shorter than that day, at Edinburgh?

6. What day of the year at Petersburg, following the 24th of December, is 12 hours longer than that day at the same place?

7. What day following the 21st of June, is 3 hours shorter than that day, at Washington?

8. How much must the sun's declination vary from the 21st of December, that the day at Cincinnati may increase one hour?

PROBLEM XXXVI.

To find the beginning, end, and duration of twilight (51) *at any place, on any given day.*

RULE.

Elevate the pole for the sun's declination on the given day, 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 12; turn the globe eastward till the given place comes to the horizon, and the hours passed over by the index will show the beginning of evening twilight; continue the motion of the globe eastward, till the given place is 18° below the horizon, measured on the quadrant of altitude, and the time passed over by the index from the beginning of twilight, will show the duration of evening twilight. The morning twilight is the same length.

Or, elevate the pole for the latitude of the given place, bring the sun's place in the ecliptic to the brass meridian, set the index to 12, and screw the quadrant of altitude on the brass meridian over the latitude of the given place; turn the globe westward on its axis, and proceed as in the above rule, only, use the sun's place in the ecliptic instead of the given place, and you will find the beginning and duration of the evening twilight.

Or, *by the Analemma.* Proceed as in the second rule, only, observe to use the given day, found on the analemma, instead of the sun's place in the ecliptic.

EXAMPLES.

1. Required the beginning, end, and duration of morning and evening twilight, at Philadelphia, on the 25th of May.

Ans. Evening twilight begins at 15 minutes past 7, and ends at 15 minutes past 9; consequently, morning twilight begins at

45 minutes past 2, and ends at 45 minutes past 4. The duration of twilight is 2 hours.

2. Required the duration of twilight at London, on the 22d of February.

3. How long does day break at Washington, before the sun rises, on the morning of the 30th of April?

4. At what time does dark night commence at Boston on the evening of June the 21st?

5. Required the beginning, end, and duration of morning and evening twilight at Dublin, on the 17th of December.

6. Required the beginning, end, and duration of morning and evening twilight at New-York, on the 5th of October.

PROBLEM XXXVII.

To find the beginning, end, and duration of constant day or twilight at any place.

RULE.

Add 18° to the latitude of the given place, count as many degrees on the brass meridian, from the north or south pole, according as the latitude is north or south, as are equal to the sum, and observe the degree where the reckoning ends; turn the globe round on its axis, and find what two points of the ecliptic* pass under that degree; opposite those points, found on the horizon, are the two days which will show the beginning and end of constant day or twilight.

Or, *by the Analemma.* Proceed as in the above rule, as far as, observe the degree where the reckoning ends; then, turn the globe round on its axis, and the two days on the analemma, which pass under the observed degree, will show the beginning and end of constant day or twilight.

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* If the sum of the latitude and 18° be less than 66° 32′ there will be no constant twilight at the given place, because this sum, counted from the north or south pole, will not reach the ecliptic.

EXAMPLES.

1. When dc the inhabitants of Petersburg begin to have constant day or twilight, and how long does it continue?

Ans. The latitude of Petersburg is 60° north, to which add 18° the sum is 78°, which count on the brass meridian from the north pole, or 12° from the equator towards the north pole; then the two points of the ecliptic which pass under 12°, are 2° in ♉, answering to the 21st of April; and 29° in ♌, answering to the 21st of August; so that the inhabitants of Petersburg, and all those who live in the same latitude, have constant day or twilight from the 21st of April to the 21st of August; that is, the sun does not descend 18° below the horizon of Petersburg during that time.

2. When do the inhabitants of Archangel begin to have constant day or twilight?

3. When does constant day or twilight begin at the North Cape in Lapland, and when does it end?

4. Have ever the inhabitants of Philadelphia twilight from sun-set to sun-rise?

5. Required the beginning of constant day or twilight at Spitzbergen.

6. When does morning twilight begin at the north pole, when does evening twilight end, and how long does total darkness continue?

Ans. 18° added to 90°, the sum is 108°, which counted from the north pole, on the brass meridian, or 18° counted from the equator towards the south pole, will show the degree of the sun's declination, when morning twilight begins, and when evening twilight ends; the days answering to this declination are the 28th of January, the beginning of morning twilight, and the 13th of November, the end of evening twilight; hence, the duration of morning twilight is from the 28th of January to the 20th of March, when the sun rises, being 51 days; and the duration of evening twilight is from the 23d of September, when the sun sets, to the 13th of November, being 51 days; and the duration of total darkness is from the 13th of November to the 28th of January, being 76 days; during this period of the absence of the sun, and the effects of his rays, the deficiency is wonderfully supplied by the *Aurora Borealis* and the moon, which shine with uncommon splendor.

PROBLEM XXXVIII.

To find in what climate (28) *any place on the globe is situated.*

RULE.

1. If the place be not in the frigid zones, find the length of the longest day at that place (by Prob. XXVII.) and from it subtract 12 hours; the whole number of half hours in the remainder* increased by one, will show the climate.

2. If the place be in the frigid zone, find the length of the longest day at that place (by Prob. XXIX.) and if its length be less than 30 days, the place is in the 25th climate, or the first within the polar circle; if its length be more than 30 days and less than 60 days, it is in the 26th climate; if more than 60 days and less than 90 days, it is in the 27th climate, &c.

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* If there be an exact number of half hours in the remainder, that number will show the climate, at the end of which, the given place is situated, or at the beginning of the next following climate.

The general rule given by writers on the globes for finding in what climate any place, not in the frigid zones, is situated, is to deduct 12 hours from the length of the longest day at the given place, and the number of half hours in the remainder, will show the climate. Let us prove the correctness of this rule by example. The fourth climate north of the equator ends in latitude 30° 48′ N., and the fifth in latitude 36° 31′ N.; now, all places situated between the parallel of 30° 48′ N. and the parallel of 36° 31′ N. are in the fifth climate north of the equator; the latitud of Savannah is 32° 3′ N.; consequently it is in the fifth climate north of the equator, and the longest day there is 14 hours 6 minutes long, from which deduct 12 hours, the remainder will be 2 hours 6 minutes, or 4 half hours; hence, Savannah is in the fourth climate; but it has been shown above to be in the fifth climate; which is absurd.

EXAMPLES.

1. In what climate is Philadelphia?

Ans. The length of the longest day at Philadelphia is 14 hours 50 minutes, from which deduct 12, the remainder will be 2 hours 50 minutes, and the whole number of half hours in this is 5, which increased by one will be 6; hence, Philadelphia is in the 6th climate north of the equator.

2. In what climate is the North Cape in latitude 71½° north?

3 In what climate is Washington, and what other places are situated in the same climate?

4. In what climate is Quebec,* and what other places are situated in the same climate?

5. In what climate is the north of Spitzbergen?

6. In what climate is Lima?

PROBLEM XXXIX.

To find the breadths of the several climates

RULE.

I. *For the northern† climates between the equator and Arctic circle.* Elevate the north pole 23½° above the northern point of the horizon, being the beginning of Cancer, to the brass meridian, and set the index of the hour circle to 12; turn the globe eastward on its axis till the index has passed over a quarter of an hour; mark with a pencil that point of the meridian passing through Libra, which is then cut by the horizon; continue the motion of the globe eastward till the index

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* It is to be observed, that all places situated on the same parallel of latitude, are in the same climate; but we must not infer from this that they have the same atmospherical temperature.

† The climates south of the equator are of the same breadth as their correspondent climates north of the equator. Or, their breadths may be found in a similar manner, by elevating the south pole 23½°, and bringing the beginning of Capricorn to the brass meridian, &c.

has passed over another quarter of an hour, and make another mark; proceed thus, till the meridian passing through Libra coincides with the under part of the brass meridian; bring these marks to the brass meridian, and the degree above each mark will show the latitude where each climate ends.

2. *For the climates within the north polar circle.* Find in what latitudes, in the north frigid zone, the longest day is 30, 60, 90 days, &c. long, (by Prob. XXXIII.) each of these latitudes will show the latitude, where each climate within the north polar circle ends.

EXAMPLES.

1. What is the breath of the 6th north climate, and what places are situated within it?

Ans. The breadth of the 6th climate is 4° 53′; it begins in latitude 36° 31′ N., and ends in latitude 41° 24′ N., and all places situated within this space, are in the same climate: we shall find them as follows: Philadelphia, Madrid, Naples, Pekin, &c.

2. What is the breadth of the 26th north climate, or the 2d within the Arctic circle?

Ans. The 26th climate begins in that latitude north, in which the length of the longest day is 30 days, and ends in that latitude north, in which the length of the longest day is 60 days; these latitudes found (by Prob. XXXIII.) will be 67° 18′ N. and 69° 33′ N.; hence, the breadth of the 26th climate is 2° 15′.

3 What is the breadth of the 9th south climate, and what places are situated within it?

4. Required the beginning, end, and breadth of the 28th climate.

5. What is the breadth of the 4th north climate, and what places are situated within it?

6. In what latitude does the 27th climate begin and end, and what places are situated within it?

TABLES OF THE CLIMATES.

1. *Climates between the Equator and the Polar Circles*

Climates.	Ends in Lat.		Where the longest day is.		Breadths of the Climates.		Climates.	Ends in Lat.		Where the longest day is.		Breadths of the Climates.	
	°	'	D.	M.	°	'		°	'	H.	M.	°	'
1	8	34	12	30	8	34	13	59	59	18	30	1	32
2	16	44	13	00	8	10	14	61	18	19	00	1	19
3	24	12	13	30	7	28	15	62	26	19	30	1	8
4	30	48	14	00	6	36	16	63	22	20	00		56
5	36	31	14	30	5	43	17	64	10	20	30		48
6	41	24	15	00	4	53	18	64	50	21	00		40
7	45	32	15	30	4	8	19	65	22	21	30		32
8	49	2	16	00	3	30	20	65	48	22	00		26
9	51	59	16	30	2	57	21	66	5	22	30		17
10	54	30	17	00	2	31	22	66	21	23	00		16
11	56	38	17	30	2	8	23	66	29	23	30		8
12	58	27	18	00	1	49	24	66	32	24	00		3

2. *Climates between the Polar Circles and the Poles.*

Climates.	Ends in Lat.		Where the longest day is.		Breadths of the Climates.		Climates.	Ends in Lat.		Where the longest day is.		Breadths of the Climates.	
	°	'	D.	M.	°	'		°	'	D.	M.	°	'
25	67	18	30 or	1	0	46	28	77	40	120 or	4	4	35
26	69	33	60	2	2	15	29	82	59	150	5	5	19
27	73	5	90	3	3	32	30	90	00	180	6	7	1

The preceding tables may be constructed by the globe, as shown above, but not with that degree of exactness given in them; therefore, recourse must be had to calculation.*

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* 1. *Construction of the first Table.*—The latitude where any climate

PROBLEM XL.

To find the sun's meridian altitude (19) *on any day at any given place.*

RULE.

Elevate the pole for the latitude of the given place, find the sun's place in the ecliptic for the given day, and bring it to that part of the brass meridian, which is numbered from the equator towards the poles; then, the number of degrees on the brass meridian, reckoning from the sun's place (the nearest way) to the horizon, will be the altitude.

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ends between the equator and polar circles, and the ascensional difference, or the time that the sun rises before 6 o'clock in that latitude on the longest day, form the sides of a right angled spherical triangle; and the angle opposite to the latitude, is equal to the complement of the sun's greatest declination; so that one side is given, namely, the sun's ascensional difference, and one angle, namely, the complement of the sun's greatest declination, to find the side opposite to the known angle. Hence, (by Baron Napier's rules) rad. × sine of the ascensional difference = tang. of the sun's greatest declination × tang. latitude.

Or, for the end of the 6th climate, where the sun rises $1\frac{1}{2}$ hours before 6, the ascensional difference is 22° 30′, it will be,

As tangent of 23° 28′	9.63761
Is to radius, sin 90° -	10.00000
So is sin of the ascensional diff. 22° 30′	9.58284
To tangent latitude 41° 24′ - - -	9.94523

2. *Construction of the second Table.*—Count half the length of the longest day at the end of any climate within the polar circle, from the 21st of June forward and backward; find the sun's declination answering to these two days in a table of the sun's declination; add these two declinations together, and divide the sum by 2, the quotient is a mean declination, which take from 90°, and the remainder will show the latitude where that climate ends.

Or, if the latitude and sun's declination be of the same name, add the sun's declination and the complement of the latitude together, the sum will be the altitude, if it does not exceed 90°; but, if this sum exceed 90°, take it from 180°, and the remainder will be the altitude. If the latitude and sun's declination be of different names, take the sun's declination from the complement of the latitude, and the remainder will be the altitude.

EXAMPLES.

1. What is the sun's meridian altitude at Philadelphia on the 29th of May?

Ans. $71\frac{3}{4}°$.

2. What is the sun's meridian altitude at Lima on the 21st of December?

3. What is the sun's greatest meridian altitude at New-Orleans?

4. What is the sun's greatest meridian altitude at Buenos Ayres?

5. What is the sun's least meridian altitude at London?

6. What is the altitude of the sun at the North Pole, (see Prob. XX.) on the 30th of April, and what is his greatest altitude there?

Examples to be worked by calculation.

1. What is the sun's meridian altitude at Madrid in latitude 40° 25′ N. on the 14th of August, when the sun's declination is 14° 25′ N.?

90°	00′	
40	25	latitude.
49	35	co. latitude.
14	25	declination.
64°	00′	the altitude sought.

2. What is the sun's meridian altitude at the Island of Barbadoes, in latitude 13° N. on the 7th of January, when the sun's declination is 22° 23′ south?

3. What is the sun's meridian altitude at Madras, in latitude 13° 5′ N. on the 15th of May, when the sun's declination is 18° 54′ N.?

4. What is the greatest meridian altitude of the sun at Washington, in latitude 38° 53′ N.?

PROBLEM XLI.

To find the sun's altitude at any particular hour of the day at any place.

RULE.

Elevate the pole for the latitude of the given place, bring the sun's place in the ecliptic for the given day to the brass meridian, and set the index of the hour circle to 12; if the given time be before noon, turn the globe eastward till the index has passed over as many hours as the given 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 given time is past noon. Keep the globe in this position, and screw the quadrant of altitude on the brass meridian over the latitude of the place; bring the graduated edge of the quadrant to coincide with the sun's place, and the number of degrees on the quadrant, between the horizon and the sun's place, will be the sun's altitude.

EXAMPLES.

1. What is the sun's altitude at Philadelphia on the 10th of May, at 10 o'clock in the morning?

Ans. 68°.

2. What is the sun's altitude at Paris on the 12th of June, at 4 o'clock in the afternoon?

3. What is the sun's altitude at Moscow on the 1st of September, at half-past 9 o'clock in the morning?

4. Required the sun's altitude at Porto Bello on the 9th of January, at 45 minutes past 10 o'clock in the morning?

5. What is the sun's altitude at Berlin on the 4th of July, when the sun is on the meridian of Philadelphia?

6. What is the sun's altitude at Lisbon on the 20th of March, when the sun is rising at Baltimore?

PROBLEM XLII.

To find the sun's least altitude on any day at any place in the north frigid zone, when the sun does not descend below the horizon.*

RULE.

Elevate the pole for the latitude of the place, bring the sun's place in the ecliptic to that part of the brass meridian, which is numbered from the poles toward the equator; and the number of degrees on the brass meridian, reckoning from the sun's place to the horizon, will be the altitude.

Or, from the sun's declination take the complement of the latitude, and the remainder will be the altitude.

EXAMPLES.

1. What is the sun's least altitude at the North Cape, in latitude $71\frac{1}{2}°$ N. on the 21st of June?

Ans. 5°.

2. What is the sun's least altitude at Disco Island, on the 21st of June?

3. What is the sun's least altitude at Spitzbergen in latitude 80° N. on the 21st of May?

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* When the sun's altitude is the least on any day at any place in the north frigid zone, it is midnight at all places in the temperate and torrid zones, situated on the same meridian as that place; and, when the sun's altitude is the greatest on any day at any place in the north frigid zone, it is noon at all places in the temperate and torrid zones, situated on the same meridian as that place. The rules to Prob. XL. will serve for finding the greatest altitude.

4. When it is midnight at Lisbon on the 2d of July, what is the sun's altitude at Bontekoe Island, in latitude $73\frac{1}{2}°$ N.?

PROBLEM XLIII.

The sun's meridian altitude and the day of the month being given, to find the latitude of the place.

RULE.

Find the sun's declination for the given day, and mark it on the brass meridian; then, if the sun was south of the observer when the altitude was taken, count on the meridian from this mark towards the south point of the horizon, as many degrees as are equal to the altitude, and observe the degree where the reckoning ends; bring this degree to coincide with the south point of the horizon, and the elevation of the pole will show the latitude north or south, according as the north or south pole is elevated. If the sun was north of the observer when the altitude was taken, count the degrees in a similar manner, from the declination towards the north point of the horizon, &c., and the elevation of the pole will show the latitude.

Or, *without the Globe.* Find the zenith distance, or the complement of the altitude, which call north if the sun was south when the altitude was taken; but, if the sun was north, call the zenith distance south; find the sun's declination in a table for that purpose; then, if the zenith distance and declination have the same name, their sum is the latitude with that name; but if they have contrary names, their difference is the latitude, and of the same name with the greater.

EXAMPLES.

1. On the 10th of May, 1846, the sun's meridian altitude was observed to be 60°, and it was south of the observer; what was the latitude of the place?

Ans. $47\frac{1}{2}°$ N.

By Calculation.

90°	00′	
60	00	S. sun's altitude at noon.
30	00	N. the zenith distance.
17	36	N. the sun's declination, 10th May, 1846.
47°	36′	N. the latitude sought.

2. On the 5th of December, 1846, the sun's meridian altitude was observed to be 80° 21′ S. of the observer; required the latitude of the place?

Ans. $12\frac{3}{4}$° S.

By Calculation.

90°	00′	
80	21	S. sun's altitude at noon.
9	39	N. the zenith distance.
22	23	S. the sun's declination, 5th Dec. 1846.
12°	44′	S. the latitude sought.

3. On the 25th of May, 1846, the sun's meridian altitude was observed to be 78° 13′ N. of the observer, required the latitude?

4. On the 1st of February, at a certain city where the clocks are 5 hours 8 minutes slower than those at London, I observed the sun's meridian altitude to be 34° S. of me; required that city?

5. On the 21st of June, at a certain city where the clocks are 1 hour 4 minutes 28 seconds slower than those at New-York, I observed the sun's meridian altitude to be 83° 30′ S. of me; required that city?

6. On the 30th of July, 1846, the meridian altitude of the sun's centre, after correction for dip, or height of the eye, and refraction, was observed to be 69° 17′, the observer being north of the sun; required the latitude?

PROBLEM XLIV.

To find the sun's amplitude (20,) *at any place on any day.*

RULE.

Elevate the pole for the latitude of the given place; find the sun's place in the ecliptic for the given day and bring it to the eastern edge of the horizon; the number of degrees from the east point of the horizon to the sun's place will show the rising amplitude; bring the sun's place to the western edge of the horizon, and the number of degrees from the west point of the horizon to the sun's place will show the setting amplitude.

Or, *by the Analemma.* Elevate the pole for the latitude of the given place, and proceed as above, only use the day of the month on the analemma, instead of the sun's place in the ecliptic.

EXAMPLES.

1. What is the sun's amplitude at Philadelphia on the 16th of July?

Ans. 28° from the east point towards the north, and 28° from the west point towards the north.

2. What is the sun's amplitude at Washington on the 9th of November?

3. On what point of the compass does the sun rise and set at London on the 30th of April?

4. On what point of the compass does the sun rise and set at Petersburg on the 21st of June?

5. On what point of the compass does the sun rise and set at the Isle of France, on the 21st of December?

6. On what point of the compass does the sun rise and set on the 20th of March?

7. How much does the sun's amplitude vary at Baltimore?

8. How much does the sun's amplitude vary at all places on the equator?

PROBLEM XLV.

To find the sun's azimuth (19,) *at any place, the day and hour being given.*

RULE.

Elevate the pole for the latitude of the given place, and screw the quadrant of altitude on the brass meridian over that degree of latitude; bring the sun's place in the ecliptic 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, but if after noon, westward, till the index has passed over as many hours as it is before or after noon; bring the graduated edge of the quadrant to coincide with the sun's place, and the number of degrees on the horizon, between the north or south point thereof and the graduated edge of the quadrant, will show the azimuth.

Or, *by the Analemma.* Proceed as in the above rule, only, use the day of the month on the analemma, instead of the sun's place in the ecliptic.

EXAMPLES.

1. What is the sun's azimuth at New-York on the 27th of May, at 10 o'clock in the morning?

Ans. The sun's azimuth is 63° from the south towards the east?

2. What is the sun's azimuth at Paris on the 10th of November, at 3 o'clock in the afternoon?

3. What is the sun's azimuth at Washington on the 21st of June, at 6 o'clock in the morning?

4. What is the sun's azimuth at Port Royal on the 21st of June, at 7 o'clock in the morning, and at 10½?*

* When the sun's declination exceeds the latitude of the place, and both of the same name, the sun will appear twice in the forenoon at dif-

5. At what time does the sun appear on the same azimuth, twice in the forenoon and twice in the afternoon, at Tobago Island, on the 20th of May?

6. At sea, in latitude 40° N. on the 15th of March, at 8 o'clock in the morning, the sun's magnetic azimuth was observed to be S. 60° 30′ E. what was the true azimuth, and the variation of the compass?

PROBLEM XLVI.

The day of the month being given, and the sun's altitude at any place, to find the hour of the day and the sun's azimuth.

RULE.

Elevate the pole for the latitude of the given place, and screw the quadrant of altitude on the brass meridian over the degree of latitude; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour circle to 12; bring the sun's place and the degree of altitude on the quadrant to coincide; then the hours passed over by the index will show the time from noon, and the number of degrees on the horizon, between the north or south point thereof, and the quadrant will show the azimuth.

EXAMPLES.

1. At what hour in the day in the afternoon,* on the 10th

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ferent times, on the same point of the compass, and again twice in the afternoon at different times, on the same point of the compass, at that place; and hence, the shadow of an azimuth dial will go back several degrees.

* The altitude of the sun at any time before noon, is equal to his altitude at the same time past noon, at any place on any day; hence, it is requisite to mention whether the observation be made before or after noon, otherwise the problem admits of two answers.

of November, is the sun's altitude 21° at Philadelphia, and what is his azimuth?

Ans. At 48 minutes past 2, and the azimuth is 43° from the south towards the west.

2. At what hour on the 11th of January is the sun's altitude 25° at Washington? The observation being made in the forenoon.

3. At what hour in the afternoon on the 21st of June, is the sun's altitude 60° at Constantinople, and what is his azimuth?

4. At what hour in the forenoon on the 16th of May, is the shadow of Washington Monument at Baltimore, equal in length to its height? and on what point of the compass does the shadow fall?

PROBLEM XLVII.

The day of the month and the sun's amplitude being given, to find the latitude of the place of observation.

RULE.

Bring the sun's place in the ecliptic for the given day to coincide with the given degree of amplitude on the horizon, by elevating or depressing the pole; then, the elevation of the pole will show the latitude.

EXAMPLES.

1. By an observation, the sun's amplitude was found to be 28° from the east towards the north, on the 17th of July; required the latitude of the place?

Ans. 40° N.

2. The sun's amplitude was observed to be 30½° from the west towards the north, on the 13th of May; required the latitude?

3. On the 18th of January, the sun's rising amplitude was observed to be 20° 41′ from the east towards the south; required the latitude?

4. At sea, on the 23d of November, I found the sun's setting amplitude to be 32° 15′ from the west towards the south, after correcting for the variation of the compass, dip of the horizon and refraction; required the latitude the ship was in?

PROBLEM XLVIII.

Given two observed altitudes of the sun, the time elapsed between them, and the day of the month, to find the latitude of the place of observation.

RULE.

Find the sun's declination, and under the degree of that declination on the brass meridian, make a mark on the globe with a pencil, set the index to 12, turn the globe on its axis till the index has passed over as many hours as are equal to the elapsed time, and under the degree of declination on the brass meridian, make another mark on the globe; then, take the complement of the first altitude from the equator in a pair of compasses, and, with one foot in one mark, and a fine pencil in the other foot, describe an arc; take the complement of the second altitude from the equator as before, and with one foot in the other mark, describe an arc to cross the former arc; bring the point of intersection to the brass meridian, and the degree above it will be the latitude sought.

EXAMPLES.

1. On the 20th of May, in north latitude, at 10 o'clock in the morning, the sun's altitude was 55° 30′, and at 1 o'clock in the afternoon, his altitude was 61° 30′; required the latitude of the place?

Ans. 45° N.

2. On the 21st of June, in north latitude, at 3 o'clock in the afternoon, the sun's altitude was 49° 30′, and at 5 o'clock the same afternoon, his altitude was 26°; required the latitude of the place?

3. On the 23d of July, the sun's altitude was 58° 40′, and after 2 hours had elapsed, his altitude was 44°; required the latitude, supposing it to be north?

4. When the sun's declination was 20° S., his altitude was 35° degrees, and after 1 hour 30 minutes had elapsed, his altitude was 42°; required the latitude of the place of observation, supposing it to be north?

PROBLEM XLIX.

Any place and the day of the month being given, to find at what time the sun will be due east or west.

RULE.

Elevate the pole for the latitude of the given place, screw the quadrant of altitude on the brass meridian over the degree of latitude, move the lower end till its graduated edge comes to the east point of the horizon, and keep it in this position; bring the sun's place in the ecliptic for the given day to the brass meridian, set the index of the hour circle to 12, and turn the globe on its axis till the sun's place comes to the graduated edge of the quadrant; the number of hours passed over by the index, will be the time from noon when the sun will be due east, and at the same time past noon he will be due west.

EXAMPLES.

1. At what hour will the sun be due east at Washington, on the 10th of May? and at what hour will he be due west on the same day?

Ans. The time from noon, when the sun is due east, is 4 hours 20 minutes; hence the sun is due east at 40 minutes past 7 in the morning, and due west at 20 minutes past 4 in the afternoon.

2. At what hours will the sun be due east and west at London, on the 21st of June?

3. At what hours will the sun be due east or west at New-York, on the 20th of March, and on the 23d of September?

4. Find at what hour the sun is due west at Baltimore, on the 27th of October; and also, how many degrees he is then below the horizon.*

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* If the length of the night at the given place exceeds the length of the day, the sun will be due east and west, when he is below the horizon.

PROBLEM L.

To find the sun's right ascension, oblique ascension, oblique descension, ascensional or descensional difference, (16, 17,) *and the time of his rising and setting at any place on any day.*

RULE.

1. *For the right ascension.* Bring the sun's place in the ecliptic for the given day to the brass meridian, then the degree on the equator cut by the brass meridian, reckoning from the point Aries eastward, will be the right ascension.

2. *For the oblique ascension and descension.* Elevate the pole for the latitude of the given place, bring the sun's place in the ecliptic to the eastern edge of the horizon, and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the oblique ascension. Bring the sun's place in the ecliptic to the western edge of the horizon, and the degree on the equator cut by the horizon, reckoning from the point Aries eastward, will be the oblique descension.

3. *For the ascensional or descensional difference.* Find the difference between the right and oblique ascension; or,* between the right and oblique descension, and this difference reduce to time (see Prob. XVI.); then, if the sun's declination and latitude of the place be of the same name, this time shows how long the sun rises before 6, and sets after 6; but, if the declination and latitude be of contrary names, this time shows how long the sun rises after 6, and sets before 6.

EXAMPLES.

1. Required the sun's right ascension, oblique ascension,

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* The difference between the right and oblique ascension, is always equal to the difference between the right and oblique descension.

oblique descension, ascensional or descensional difference, and the time of his rising and setting at Philadelphia, on the 25th of May.

Ans. The right ascension is 62°, the oblique ascension is 43° 15′, and the oblique descension is 80° 45′, the ascensional difference is 62° 00′ — 43° 15′ = 18° 45′, and the descensional difference is 80° 45′ — 62° 00′ = 18° 45′, the same as the ascensional difference; this difference reduced to time, gives 1 hour 15 minutes; consequently, the sun rises 1 hour 15 minutes before 6, or at 45 minutes past 4; and sets 1 hour 15 minutes after 6, or at 15 minutes past 7.

2. What are the sun's right ascension, oblique ascension, oblique descension, ascensional or descensional difference, and the time of his rising, and setting at Washington, on the 7th of January?

3. Find the sun's right ascension, oblique ascension, ascensional difference, and the time of his rising and setting at Paris, on the 21st of June.

4. What are the sun's right ascension, declination, oblique ascension, oblique descension, ascensional or descensional difference, rising amplitude, setting amplitude, and the time of his rising and setting at New-York, on the 21st of December?

PROBLEM LI.

*To find that part of the equation of time, or the difference between the time shown by a well regulated clock, and a true sun-dial, which depends upon the obliquity of the ecliptic.**

RULE.

Bring the sun's place in the ecliptic to the brass meridian, then count the number of degrees from Aries to

* The true equation of time, or the difference between the time shown by a well regulated clock, and a true sun-dial, cannot be determined by the globe; because it depends upon two causes, namely, the obliquity of the ecliptic, and the irregular motion of the earth in its orbit; and hence, this difference of time can only be found by the globe, so far as it depends upon the obliquity of the ecliptic.

the brass meridian, on the equator and on the ecliptic; the difference reduced to time, counting four minutes of time to a degree, will be the equation of time. If the number of degrees on the equator exceed those on the ecliptic, the sun is slower than the clock; but, if the number of degrees on the ecliptic exceed those on the equator, the sun is faster than the clock.

EXAMPLES.

1. What is the equation of time which depends upon the obliquity of the ecliptic, on the 30th of April?

Ans. The degrees on the ecliptic exceed the degrees on the equator by $2\frac{1}{2}$; hence, the sun is 10 minutes faster than the clock.

2. Required the equation of time on the 31st of July?

3. What is the equation of time dependent on the obliquity of the ecliptic, on the 14th of January?

4. On what four days of the year is the equation of time nothing?

PROBLEM LII.

The day and hour being given when a solar eclipse will happen, to find where it will be visible.

RULE.

Find the place on the globe to which the sun is then vertical, (by Prob. XXII.) bring this place to the brass meridian, and elevate the pole for its latitude; then at most of the places above the horizon, the eclipse may be visible.*

* If the moon changes in the node, her shadow or penumbra falls perpendicularly upon the earth in the form of a circle; and the place on the earth where the sun is vertical, is the centre of the penumbral shadow at the middle of the general eclipse. When the moon is in apogee, and the sun in perigee, the penumbral shadow may cover a circular space on the earth of 4,800 miles, or $69\frac{1}{4}°$ diameter. (196.)

When the moon changes short of her descending node, the penumbral

EXAMPLES.

1. On the 12th of February, 1850, there will be an eclipse of the sun, at 1 hour 33 minutes in the morning, New-York time; where will it be visible?

Ans. In the south-eastern part of Africa, in the Indian Ocean, and in China.

2. On the 7th of August, 1850, at 4 hours 38 minutes in the afternoon, New-York time, there will be an eclipse of the sun; where might it be visible, supposing the moon's penumbral shadow to cover a circular space on the earth of $69\frac{1}{4}°$ diameter?

NOTE.—The learner may consult the Almanacs for more examples.

PROBLEM LIII.

The day and hour being given when a lunar eclipse will happen, to find where it will be visible.

RULE.

Find the place on the globe to which the sun is then vertical, (by Prob. XXII.) bring this place to the brass meridian, and observe its latitude; keep the globe from

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shadow passes over the northern parts of the earth; and when she changes past the same node, the penumbral shadow passes over the southern parts of the earth; but when she changes short of the ascending node, the penumbral shadow passes over the southern parts of the earth; and when she changes past the same node, the penumbral shadow passes over the northern parts of the earth. The farther the moon changes from either node, within the ecliptic limits (198), the less will the part of the penumbral shadow be which falls upon the earth.

And, because the moon may change as well in one node as in another, and at different distances from them, it follows that the variety of eclipses are almost innumerable; hence, if the extent of the penumbral shadow be not accurately found by calculation, it is utterly impossible to find by the globe where a solar eclipse will be visible.

revolving on its axis, and if the latitude be north, elevate the south pole so many degrees above the horizon as are equal to that latitude; but, if it be south, elevate the north pole in a similar manner; set the index of the hour circle to 12; turn the globe on its axis till the index has passed over 12 hours, or till it points to the other 12; then to all places above the horizon the eclipse will be visible; to that place which is antipodes of the place where the sun is vertical, the moon will be vertically eclipsed; to all places along the western edge of the horizon, she will rise eclipsed; and to all places along the eastern edge of the horizon, she will set eclipsed.

EXAMPLES.

1. On the 19th of March, 1848, the middle of an eclipse of the moon was at 9 hours 12 minutes, Greenwich astronomical time; where was it visible?

Ans. It was visible to Asia, Europe, and Africa.

2. On the 8th of March, 1849, the middle of a lunar eclipse was at 54 minutes past 7 in the evening; where was it visible?

NOTE.—For more examples, the learner may consult the Almanac for any year.

PROBLEM LIV.

To find the difference in the time of the Harvest Moon's daily rising (110), *at any place.*

RULE.

1. *For north latitude.* Elevate the pole for the latitude of the given place, make a mark on every 12° * of the ecliptic with a pencil; preceding and following the point Aries, till there are seven or eight marks, bring that mark which is the nearest to Pisces to the eastern edge of the horizon, and set the index of the hour circle to 12;

* The moon's daily gain in longitude over the sun is 12° 11′ 27″. (96).

turn the globe westward on its axis till the other marks successively come to the horizon; the time passed over by the index, between the coming of any mark to the horizon, and that following, will show the difference of time between the moon's rising on any two nights, when she is in or near those marks. If the same marks be brought to the western edge of the horizon, and you proceed in a similar manner, the difference between the time of the moon's setting may be found. When the difference between the time of her rising is the least, the difference between the time of her setting will be the greatest; and the contrary.

2. *For south latitude.* Elevate the pole for the latitude of the place, make a mark on every 12° of the ecliptic with a pencil, preceding and following the point Libra, till there are seven or eight marks; bring that mark which is nearest to Virgo, to the eastern edge of the horizon, and set the index of the hour circle to 12; then, proceed precisely as in the above rule, and you will find the difference between the time of the harvest moon's rising, which happens about the time of the vernal equinox.

PROBLEM LV.

To place the terrestrial globe in the sunshine, so that it may represent the natural position of the earth.

RULE.

Place the globe directly north and south by the compass, taking care to make a proper allowance for the variation; let the wooden horizon be perfectly horizontal; bring the place in which you are situated to the brass meridian, and elevate the pole for its latitude; then the globe will correspond in every respect with the situation of the earth itself. The poles of the globe will be directed towards the poles in the heavens, the meridians, parallels of latitude, tropics, and all the circles on the globe, will correspond with the same imaginary circles in the heavens; and each kingdom, country, and state, will be directed 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; and hence, at one view, may be seen all those places which have day, and those which have night, &c.

PROBLEM LVI.

To find the hour of the day at any place, by placing the globe in the sunshine.

RULE.

Place the globe due north and south upon a horizontal plane, by the compass, allowing for the variation, and elevate the pole for the latitude of place; bring the sun's place in the ecliptic to the brass meridian, and set the index of the hour circle to 12; 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, keep the globe in this position, and the number of hours passed over by the index will show the time from noon, hence the hour of the day is easily obtained.

PROBLEM LVII.

To find the sun's altitude, by placing the globe in the sunshine.

RULE.

Place the globe upon a horizontal plane, stick a needle 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; the elevation of the pole above the horizon will be the sun's altitude.

PROBLEM LVIII.

To find the sun s declination and his azimuth, by placing the globe in the sunshine.

RULE.

Place the globe due north and south upon a horizontal plane, by the compass, or by a meridian line,* and elevate the pole for the latitude of the place; then if the sun shines over the north pole, his declination is as many degrees north as he shines over the pole; if the sun does not shine so far as the north pole, his declination is as many degrees south, as the enlightened part is distant from the pole.

Observe the degree of the sun's declination on the brass meridian, and stick a needle perpendicularly in the globe under that degree; turn the globe on its axis till the needle casts no shadow; keep the globe in this position, and screw the quadrant of altitude over the degree of latitude; bring the graduated edge of the quadrant to coincide with the point where the needle is fixed, and the degree on the horizon will show the azimuth.

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* A meridian line may be drawn in the following manner. Describe a circle on a horizontal plane, in the centre of which fix a straight wire perpendicular to the plane; mark in the morning where the end of the shadow touches the circumference of the circle; in the afternoon mark where the end of the shadow touches the circumference of the same circle; and, divide the arc of the circle contained between these two marks into two equal parts; a line drawn from the point of division to the centre of the circle, will be a true meridian, or north and south line. If this line be intersected by a perpendicular, that perpendicular will be an east and west line; thus you will have the four cardinal points of the horizon.

PROBLEM LIX.

To make a horizontal sun-dial for any latitude

RULE.

Elevate the pole for the latitude of the place, and bring the point Aries to the brass meridian, then, as globes in general, have meridians drawn through every 15° of longitude, eastward and westward from the point Aries, observe where the meridians intersect the horizon, and count the number of degrees between the brass meridian and each of the points of intersection; the hour arcs will respectively contain these degrees. The dial must be numbered 12 at the brass meridian, thence, 11, 10, 9, 8, 7, 6, 5, &c., towards the west, for morning hours; and 1, 2, 3, 4, 5, 6, 7, &c., towards the east, for evening hours.

It is unnecessary to draw any more hours, than what will answer to the sun's continuance above the horizon on the longest day at the given place. The style or gnomon of the dial must be fixed in the centre of the dial-plate, and elevated as many degrees above the plane of which, as are equal to the latitude of the place. The dial must be placed, so that the hour 12 may be directed towards the north, if the latitude be north, with the upper part of the gnomen parallel to the earth's axis.

Let it be required to make a horizontal dial for the latitude of Baltimore.

Elevate the north pole 39° 17′ above the horizon, and bring the point Aries to the brass meridian; then you will find the degrees on the eastern part of the horizon, between the brass meridian and the meridians on the globe, to be as follows, namely, 9° 38′, 20° 5′, 32° 20′, 47° 38′, 67° 4′, and 90°, for the hours 1, 2, 3, 4, 5, and 6, in the afternoon; and on the western part of the horizon, the hour arcs will contain the same degrees, for the hours 11, 10, 9, 8, 7, and 6, in the morning.

The following table,* shows not only the hour arcs, but the halves and quarters from 12 to 6.

Hours.	Hour Angles.	Hour Arcs.	Hours.	Hour Angles.	Hour Arcs.
12¼	3° 45′	2° 23′	3¼	48° 45′	35° 50′
12½	7 30	4 46	3½	52 30	39 32
12¾	11 15	7 11	3¾	56 15	43 28
1	15 0	9 38	4	60 0	47 38
1¼	18 45	12 8	4¼	63 45	52 5
1½	22 30	14 42	4½	67 30	56 48
1¾	26 15	17 20	4¾	71 15	61 48
2	30 0	20 5	5	75 0	67 4
2¼	33 45	22 56	5¼	78 45	72 34
2½	37 30	25 55	5½	82 30	78 15
2¾	41 15	29 3	5¾	86 15	84 5
3	45 0	32 20	6	90 0	90 0

PROBLEM LX.

To make a vertical sun-dial, facing the south, in north latitude.

RULE.

Elevate the south pole for the complement of the latitude of the given place, and bring the point Aries to the brass meridian; then, as globes in general have meridians drawn through every 15° of longitude from the point Aries, observe where the meridians intersect the horizon, and count the number of degrees between the

* While the globe remains in the position described in the rule, it will be seen that a right-angled spherical triangle is formed, the perpendicular of which is the latitude, the base the hour arc, and the vertical angle the hour angle. Hence, for 2 hours, we have

as cotang. hour angle 30° ar. co. —	1.761439
is to Radius 90° -	10.000000
so is sin. latitude 39° 17′	9.801511
to tang. hour arc 20° 5′ -	9.562950

brass meridian and each of the points of intersection; the hour arcs will respectively contain these degrees. The dial must be numbered 12 at the brass meridian, thence, 11, 10, 9, 8, 7, 6, towards the west for morning hours; and 1, 2, 3, 4, 5, 6, towards the east, for evening hours. It is unnecessary to draw any more hours on such a dial, than these, because the sun cannot shine longer upon it than 12 hours in the course of one day The style or gnomon must be parallel to the earth's axis, and elevated as many degrees above the plane of the dial-plate, as are equal to the complement of the latitude

Let it be required to make a vertical dial, facing the south, for the latitude of Baltimore.

Elevate the south pole 50° 43′ above the horizon, and bring the point Aries to the brass meridian; then, you will find the degrees on the eastern part of the horizon, between the south point and the meridians on the globe, to be as follows, namely, 11° 43′, 24° 5′, 37° 44′, 53° 17′, 70° 54′, and 90°, for the hours 1, 2, 3, 4, 5, and 6, in the afternoon; and on the western part of the horizon, the hour arcs will contain the same degrees, for the hours, 11, 10, 9, 8, 7, and 6, in the morning.

The following table is calculated precisely in the same manner as the table in the preceding problem by using the complement of the latitude instead of the latitude.

Hours.	Hour Angles.	Hour Arcs.	Hours.	Hour Angles.	Hour Arcs.
12¼	3° 45′	2° 54′	3¼	48° 45′	41° 26′
12½	7 30	5 49	3½	52 30	45 15
12¾	11 15	8 45	3¾	56 15	49 12
1	15 0	11 43	4	60 0	53 17
1¼	18 45	14 43	4¼	63 45	57 30
1½	22 30	17 47	4½	67 30	61 51
1¾	26 15	20 54	4¾	71 15	66 19
2	30 0	24 5	5	75 0	70 54
2¼	33 45	27 21	5¼	78 45	75 35
2½	37 30	30 42	5½	82 30	80 21
2¾	41 15	34 10	5¾	86 15	85 10
3	45 0	37 44	6	90 0	90 0

It may be observed, that the time shown by a sun-dial is the apparent time, and not the true or mean time of the day, as shown by a well regulated clock. (26.) The following table of the equation of time will show how much a clock should be faster or slower than a sun-dial. Every sun-dial should have such a table engraven upon it.

Days and Months.	Minutes.	Days and Months.	Minutes.	Days and Months.	Minutes.
Jan. 1	4 (Clock faster than the Dial.)	19	1 (Clock slower.)	24	8 (Clock slower than the Dial.)
3	5	23	2	27	9
5	6	30	3	30	10
7	7	May 13	4	Oct. 3	11
9	8	29	3	6	12
12	9	June 5	2	10	13
15	10	10	1	14	14
18	11	15	0	19	15
21	12	*		27	16
25	13	20	1 (Clock faster.)	Nov. 15	15
31	14	25	2	20	14
Feb. 10	15	29	3	24	13
21	14	July 5	4	27	12
27	13	11	5	30	11
March 4	12	28	6	Dec. 2	10
8	11	Aug. 9	5	5	9
12	10	15	4	7	8
15	9	20	3	9	7
19	8	24	2	11	6
22	7	28	1	13	5
25	6	31	0	16	4
28	5	*		18	3
April 1	4	Sept. 3	1 (Clock slower.)	20	2
4	3	6	2	22	1
7	2	9	3	24	0
11	1	12	4	*	
15	0	15	5	26	1 (Cl. fast.)
		18	6	28	2
		21	7	30	3

CHAPTER II.

PROBLEMS PERFORMED BY THE CELESTIAL GLOBE.

PROBLEM I.

To find the right ascension and declination of any star.

RULE.*

Bring the given star to that part of the brass meridian which is numbered from the equinoctial towards the poles; the degree on the brass meridian above the star is the declination, and the degree on the equinoctial cut by the brass meridian, reckoning from the point Aries eastward, is the right ascension.

EXAMPLES.

1. Required the right ascension and declination of α, *Arcturus*, in the right thigh of Bootes.

Ans. Right ascension 211° 55′, declination 20° 8′ N.

2. Required the right ascension and declinations of the following stars:

β, *Arided*, in Cygnus,	α, *Arietis*, in Aries,
γ, *Algorab*, in the Crow,	α, *Castor*, in Gemini,
α, *Canopas*, in Argo Navis,	β, *Algol*, in Perseus,
β, *Rigel*, in Orion,	α, *Altair*, in the Eagle,
α, *Spica Virginis*, in Virgo,	α, *Antares*, in the Scorpion,
ε, *Mirach*, in Bootes,	α, *Schedar*, in Cassiopeia.

* This rule will answer for finding the sun's right ascension and declination, by using the sun's place in the ecliptic, instead of the given star. The right ascension and declination of the moon and planets must be found from the Nautical Almanac.

PROBLEM II.

*To find the latitude and longitude of any star.**

RULE.

Bring the north or south pole of the ecliptic, according as the star is on the north or south side of the ecliptic, to the brass meridian, and 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; then, the degree on the quadrant over the star is its latitude, and the number of degrees on the ecliptic, reckoning from the point Aries eastward to the quadrant, is its longitude.

EXAMPLES.

1. Required the latitude and longitude of α, *Markab*, in Pegasus.

Ans. Latitude 19° 25′ N., and longitude 11 signs 20° 54′.

2. Required the latitudes and longitudes of the following stars:

α, *Altair*, in the Eagle,
β, *Mirach*, in Andromeda,
α, *Arcturus*, in Bootes,
α, *Aldebaran*, in Taurus,
γ, *Vega*, in Lyra,
α, *Fomalhaut*, in the S. Fish
α, *Sirius*, in Canis Major,
α, *Regulus*, in Leo,
β, *Rigel*, in Orion,
γ, *Bellatrix*, in Orion,
α, *Capella*, in Auriga,
α, *Procyon*, in Canis Minor,
α, *Rastaben*, in Draco,
β, *Pollux*, in Gemini,
β, *Algol*, in Perseus,
γ, *Algenib*, in Pegasus.

* The latitudes and longitudes of the moon and planets must be found from the Nautical Almanac, or an Ephemeris; because, they cannot be placed on the globe, as the stars are placed, on account of their continual motion.

PROBLEM III.

The right ascension and declination of the moon, a star, or a planet, being given, to find its place on the globe.

RULE.

Bring the given degree 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 the place of the moon or planet.

EXAMPLES.

1. What star has 163° 6′ of right ascension, and 62° 44′ N. declination?

Ans. α, *Dubhe*, in the back of the Great Bear.

2. On the 10th of September, 1848, the moon's right ascension was 20 hours 54 minutes, and her declination 13° 58′, S. find her place on the globe at that time.

Ans. About 4° in Pisces, nearly in the plane of the ecliptic.

3. What stars have the following right ascensions and declinations?

RIGHT ASCEN.	DECLIN.	RIGHT ASCEN.	DECLIN.
29° 14′	22° 36′ N.	22*h.* 47*m.*	20° 35′ S.
86 20	7 22 N.	20 35	44 38 N.
176 3	54 42 N.	4 27	16 12 N.

4. On the 13th of December, 1848, the declination of Mars was 21° 3′ S. and his right ascension 16 hours 8 minutes; find his place on the globe at that time.

5. On the 25th of December, 1848, the right ascension of Jupiter was 9 hours 38 minutes 53 seconds, and his declination 14° 59′ 34″ N.; find his place on the globe.

6. On the 31st of December, 1848, the right ascension of Saturn was 23 hours 26 minutes 18 seconds, and his declination 5° 58′ 58″ S.; find his place on the globe.

PROBLEM IV.

The latitude and longitude of the moon, a star, or a planet, being given, to find its place on the globe.

RULE.

Bring the north or south pole of the ecliptic, according as the latitude is north or south, to the brass meridian, and 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 cuts the given degree of longitude on the ecliptic; then under the given latitude, on the quadrant, you will find the star, or the place of the moon or planet.

EXAMPLES.

1. What star has 2 signs 7° 12′ of longitude, and 5° 28′ S. latitude?

Ans. *α*, *Aldebaran*, in Taurus.

2. What stars have the following latitudes and longitudes?

LAT.			LON.			LAT.			LON.		
6°	40′	N.	3s	20°	40′	19°	25′	N.	11s	20°	54′
9	58	N.	1	5	5	4	33	S.	8	7	11
21	7	S.	11	1	15	29	19	N.	9	29	10
16	3	S.	2	25	51	39	33	S.	3	11	13
22	52	N.	2	18	57	10	4	N.	3	17	21
12	35	S.	1	11	25	44	20	N.	7	9	22

3. On the 9th of December, 1848, at midnight, the moon's longitude was 2 signs 11° 9′, and her latitude 4° 59′ S.; required her place on the globe?

4. On the 15th of May, 1848, the longitude of Venus was 36° 15′, and latitude 1° 24′ S.; required her place on the globe?

PROBLEM V.

The month, day, and hour of the day at any place being given, to place the globe in such a manner as to represent the heavens at that time and place; in order to find the relative situations and names of the constellations and principal stars.

RULE.

Place the globe, on a clear star-light night, due north and south by the compass, upon a horizontal plane, where the surrounding horizon is uninterrupted by different objects, and elevate the pole for the latitude of the place; find the sun's place in the ecliptic for the given day, 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; keep 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 VI.

The month, day, and hour of the day at a place being given, to find what stars are rising, setting, culminating, (19,) *&c.*

RULE.

Elevate the pole for the latitude of the place, bring the sun's place in the ecliptic 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; keep the globe in this position; then, all the stars along the eastern edge of the horizon will be rising at the given place, those along the western edge will be setting, those under the brass meridian above the horizon will be culminating, those above the horizon will be visible, and those below the horizon will be invisible. If the globe be turned on its axis from east to west, those stars which do not descend below the horizon, never set at the given place; and those which do not ascend above the horizon, never rise.

EXAMPLES.

1. On the 21st of October, when it is 7 o'clock in the evening at Philadelphia, what stars are rising, what stars are setting, and what stars are culminating?

Ans. Menkar in Cetus, is rising; *Capella,* a little above the eastern edge of the horizon, *Deneb,* on the meridian, *Arcturus,* a little east of the western edge of the horizon; *Antares,* in the Scorpion, setting, &c.

2. On the 16th of January, when it is three o'clock in the morning at Baltimore, what stars are rising, what stars are setting, and what stars are culminating?

Ans. Deneb is rising, *Dubhe* culminating, *Alamak* in Andromeda, setting, &c.

3. On the 10th of November, when it is ten o'clock in the evening, at Washington, what stars are rising, what stars are setting, and what stars are culminating?

4. What stars never set at Paris, and what stars never rise at the same place?

5. How far northward must a person travel from New-York, to lose sight of *Antares?*

6. How far southward must a person travel from Mexico, to lose sight of *Dubhe?*

7. In what latitude do those reside, to whom *Sirius* is never visible, but when in their horizon?

8. In what latitude is *Aldebaran* always vertical, when on the meridian?

PROBLEM VII.

The month and day being given, to find at what hour of the day any star, or planet, will rise, culminate, and set at any given place.

RULE.

Elevate the pole for the latitude of the given place, bring the sun's place in the ecliptic for the given day 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 on its axis till the star, &c., comes to the eastern edge of the horizon, the brass meridian, and the western edge of the horizon successively; the hours passed over by the index in each case, will show the time from noon, that the star or planet rises, culminates, and sets.

If the star, &c., be above the horizon and east of the brass meridian, find the time of culminating, setting, and rising, in a similar manner; but, if it be west of the brass meridian, then you will find the time of setting, rising and culminating.

EXAMPLES.

1. At what time will *Arcturus* rise, culminate, and set at Washington, on the 21st of August?

Ans. It will rise 45 minutes past 8 o'clock in the morning, culminate at 4 in the afternoon, and set at 15 minutes past 11 o'clock at night.

2. On the 14th of December, 1848, the right ascension of Venus was 301° 13′, and her declination 22° 23′ S., at what time did she rise, culminate, and set, at Baltimore, and was she a morning or an evening star?

Ans. Venus culminated at 32 minutes past 2 o'clock in the

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* The planet's place on the globe must be determined by Prob. III. or IV

afternoon, set at 16 minutes past 7, and rose at 6 minutes before 10. Venus was an evening star, because she set after the sun.

3. At what time will *Sirius* rise, culminate, and set at New-York, on the 25th of December?

4. On the 8th of September, 1848, the right ascension of Jupiter was 8 hours 57 minutes 12 seconds, and his declination 17° 47′ N., at what time did he rise, culminate, and set, at Washington, and was he a morning or an evening star?

5. On the 3d of October, 1848, the right ascension of Saturn was 23 hours 28 minutes 45 seconds, and his declination 5° 59′ 6″ S., at what time did he rise, culminate, and set, at Boston?

PROBLEM VIII.

RULE.

The month and day being given, to find all those stars that rise and set achronically, cosmically, and heliacally (24), *at any given place.*

ve.

Elevate the pole for the latitude of the given place. Then,

1. *For the achronical rising and setting.* Bring the sun's place in the ecliptic to the western edge of the horizon, and all the stars along the eastern edge of the horizon will rise achronically, while those along the western edge will set achronically.

2. *For the cosmical rising and setting.* Bring the sun's place to the eastern edge of the horizon; and all the stars along that edge of the horizon will rise cosmically, while those along the western edge will set cosmically.

3. *For the heliacal rising and setting.* Screw the quadrant of altitude on the brass meridian over the degree of latitude, turn the globe eastward on its axis till the sun's place cuts the quadrant 12° below* the eastern

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* The brighter a star is when above the horizon, the less will the sun be depressed below the horizon, when that star first becomes visible

edge of the horizon; then, all stars of the first magnitude, along the same edge of the horizon, will rise heliacally; continue the motion of the globe till the sun's place intersects the quadrant in 13°, 14°, 15°, &c., below the horizon, and you will find the stars of the second, third, fourth, &c., magnitudes, which rise heliacally, at the given place on the given day. Bring the quadrant to the western edge of the horizon, turn the globe westward on its axis, till the sun's place intersects the quadrant in a similar manner as before, and you will find all the stars that set heliacally.

EXAMPLES.

1. What stars rise and set achronically at Washington, on the 1st of January?

Ans. Castor in Gemini, *Betelguese* in Orion, &c., rise achronically; and δ in Bootes, γ in Hercules, &c., set achronically.

2. What stars rise and set cosmically at Philadelphia, on the 2d of June?

Ans. Aldebaran, and β in Taurus, &c., rise cosmically, and *Arcturus*, &c., in Bootes, set cosmically.

3. What star of the first magnitude rises heliacally at New-York, on the 25th of June?

Ans. Aldebaran in Taurus.

4. What star of the first magnitude sets heliacally at Baltimore, on the 22d of January?

Ans. Altair in the Eagle.

5. What stars rise and set cosmically at Dublin, on the 14th of November?

6. What stars rise and set achronically at London, on the 27th of April?

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hence, the heliacal rising and setting of the stars will vary according to their different degrees of magnitude and brilliancy. According to Ptolemy, stars of the first magnitude are seen rising and setting when the sun is 12° below the horizon, stars of the second magnitude when the sun is 13° below the horizon, stars of the third magnitude 14°, and so on, reckoning one degree for each magnitude.

PROBLEM IX.

To find the time of the year at which any given star rises or sets achronically, at a given place.

RULE.

Elevate the pole for the latitude of the given place, bring the given star to the eastern edge of the horizon, observe what degree of the ecliptic is cut by the western edge of the horizon; and, the day of the month answering to that degree will show the time when the star rises achronically, or when it begins to be visible in the evening. Bring the given star to the western edge of the horizon, observe what degree of the ecliptic is cut by the same edge of the horizon; and the day of the month answering to that degree will show the time when the star sets achronically, or when it ceases to appear in the evening.

EXAMPLES.

1. At what time does *Arided* rise achronically at Baltimore, and on what day of the year does it set achronically?

Ans. Arided rises achronically on the 21st of May, and it sets achronically on the 22d of March.

2. On what day of the year does *Arcturus* rise achronically at Washington, and at what time does it set achronically?

3. On what day of the year does *Aldebaran* begin to be visible in the evening at Glasgow, and on what day does it cease to appear in the evening?

4. At what time does *Procyon* in Canis Minor rise achronically at New-York, and on what day of the year does it set achronically?

5. On what day of the year does *Spica Virginis* set achronically, or cease to appear in the evening, at Baltimore?

PROBLEM X.

RULE.

To find the time of the year at which any given star rises or sets cosmically, at a given place.

Elevate the pole for the latitude of the given place, bring the given star to the eastern edge of the horizon, and observe what degree of the ecliptic is cut by the same edge of the horizon; the month and day of the month answering to that degree, will show the time when the star rises cosmically, or when it rises with the sun. Bring the given star to the western edge of the horizon, and observe what degree of the ecliptic is cut by the eastern edge; the month and day of the month answering to that degree, will show the time when the star sets cosmically, or when it sets at sun-rising.

EXAMPLES.

1. At what time of the year does *Procyon* in Canis Minor, rise cosmically at Washington; and, at what time does the same star set cosmically at the same place?

Ans. Procyon rises cosmically on the 24th of July, or rises with the sun on that day, and sets cosmically on the 25th of December, or sets at sun-rising on that day.

2. At what time of the year does *Regulus* rise cosmically at New-York, and at what time does it set cosmically?

3. At what time of the year does *Bellatrix* in Orion rise with the sun at London, and at what time does it set at sun-rising?

4. At what time of the year does *Arcturus* rise with the sun at Philadelphia; and at what time of the year will it set, when the sun rises at the same place?

5. At what time of the year do the *Pleiades* rise cosmically at Baltimore; and at what time do they set cosmically at the same place?

PROBLEM XI.

To find the time of the year at which any given star rises or sets heliacally, at a given place.

RULE.

Elevate the pole for the latitude of the given place, and screw the quadrant of altitude on the brass meridian over the degree of latitude; bring the given star to the eastern edge of the horizon, and move the quadrant till it cuts the ecliptic 12° below* the eastern edge of the horizon, if the star be of the first magnitude; 13° if it be of the second magnitude; 14° if it be of the third magnitude, and so on; the degrees of the ecliptic cut by the quadrant will show, on the horizon, the day of the month, when the star rises heliacally. Bring the given star to the western edge of the horizon, and move the quadrant of altitude till it cuts the ecliptic below the western edge of the horizon, in a similar manner as before; the degree of the ecliptic cut by the quadrant will show, on the horizon, when the star sets heliacally.

EXAMPLES.

1. At what time of the year does *Arcturus* rise heliacally at Jerusalem, and at what time does it set heliacally at the same place?

Ans. Arcturus will rise heliacally on the 23d of October, that is, when it first becomes visible in the morning, after having been so near the sun as to be hid by the splendor of his rays; and, *Arcturus* will set heliacally on the 7th of November, that is, when it first becomes invisible in the evening, on account of its nearness to the sun.

2. At what time of the year does *Sirius*, or the Dog Star, rise heliacally at Rome, and at what time does it set heliacally at the same place?

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* See the note to Prob. VIII

3. What time of the year does *Procyon* rise heliacally at New-York, and at what time does it set heliacally at the same place ?

4. At what time of the year does *Spica Virginis* rise heliacally at London, and at what time does it set heliacally at the same place ?

PROBLEM XII.

To find the diurnal arc (25,) *of any star, or its continuance above the horizon for any day at a given place.*

RULE.

Elevate the pole for the latitude of the given place, bring the given star to the eastern edge of the horizon, and set the index of the hour circle to 12 ; turn the globe westward on its axis 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 its continuance above the horizon for any day, at the given place.

EXAMPLES.

1. What is the diurnal arc of *Regulus,* or its continuance above the horizon for one day at New-York ?

Ans. 13 hours 35 minutes.

2. What is the diurnal arc of *Sirius,* at London ?

3. *Aldebaran* in Taurus, rises cosmically at Philadelphia, on the 2d of June, does that star set before or after the sun on the same day, and how long ?

4. What is the diurnal arc of *Arcturus* at Washington ?

5. How long does *Procyon* continue above the horizon, during one revolution of the earth on its axis, at Baltimore ?

6. What is the diurnal arc of *Capella* at Rome ?

7. *Arietis* sets cosmically at Baltimore on the 31st of October, how long does that star rise before the sun sets on the same day ?

8. What is the diurnal arc of *Pollux* at Quebec ?

PROBLEM XIII.

To find the oblique ascension and descension of any star, and its rising and setting amplitude, at a given place

RULE.

Elevate the pole for the latitude of the given place, and bring the given star to the eastern edge of the horizon, then the degree of the equinoctial cut by the same edge of the horizon, will be the oblique ascension, and the number of degrees between the star and the eastern point of the horizon will be its rising amplitude: turn* the globe westward on its axis till the given star comes to the western edge of the horizon, then the degree of the equinoctial cut by the same edge of the horizon, will be the oblique descension, and the number of degrees between the star and the western point of the horizon, will be its setting amplitude.

EXAMPLES.

1. Required the oblique ascension and descension of *Castor*, and its rising and setting amplitude, at Philadelphia.

Ans. The oblique ascension is 78°, oblique descension 144°; rising amplitude 45° to the north of the east, and setting amplitude 45° to the north of the west.

2. Required the oblique ascension and descension of *Regulus*, and its rising and setting amplitude at New-York?

3. Required the oblique ascension, oblique descension, and its rising and setting amplitude of γ in Leo, at Washington?

4. Required the rising and setting amplitude of *Arcturus*, its oblique ascension, and oblique descension, at London?

5. Required the rising and setting amplitude of α Aquilæ, its oblique ascension, and oblique descension, at Baltimore?

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* The star's diurnal arc may here be found, by observing the number of hours passed over by the index, during this motion of the globe on its axis.

PROBLEM XIV.

To find the distance in degrees between any two stars, or the angle which they subtend, as seen by a spectator on the earth.

RULE.

Lay the graduated edge of the quadrant of altitude over the two given stars, so that the division marked 0 may be on one of the stars; the degrees on the quadrant comprehended between the two stars will be their distance, or the angle which they subtend, as seen by a spectator on the earth.

EXAMPLES.

1. What is the difference between *Arcturus* and *Dubhe?* *Ans.* 54°.
2. What is the distance between α in Serpentarius, and γ in Cygnus ?
3. What is the distance between *Lyra* and *Mirach?*
4. What is the distance between *Gemma* and *Antares?*
5. What is the distance between *Alioth* in the tail of the Great Bear, and β in the tail of Leo ?
6. What is the distance between *Deneb* and *Menkar?*

PROBLEM XV.

To find the meridian altitude of a star or planet, on any day, at a given place.*

RULE.

Elevate the pole for the latitude of the given place,

* It is not requisite to give the day of the month, in finding the meridian altitude of the stars, because it is invariable at the same place

and bring the given star or planet's* place on the globe to the brass meridian; then the number of degrees on the meridian, contained between the star or planet's place and the horizon, will be the altitude required.

EXAMPLES.

1. What is the meridian altitude of *Aldebaran* in Taurus, at Washington?

Ans. $67\frac{1}{4}°$

2. What is the meridian altitude of *Arcturus* at Paris?

3. What is the meridian altitude of *Capella* at Baltimore?

4. On the 1st of January, 1848, the right ascension of Mars was 2 hours 12 minutes 7 seconds, and declination 14° 43′ 44″ N.; what was his meridian altitude at New-York?

5. On the 6th of December, 1848 the moon passed the meridian of Baltimore at 8 hours 42 minutes,† when her right

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* The moon or planet's place on the globe must be determined by Prob. III. or IV.

† The longitude of Baltimore is 76° 39′ = 5*h.* 7*m.* west of Greenwich. On the 6th and 7th of December, 1848, the moon's meridian passages were at 8*h.* 30*m.* and 9*h.* 25*m.* Greenwich mean time, the difference is 55*m.*; therefore, 24*h.* : 55*m.* :: 5*h.* 7*m.* : 12*m.*, which added to the Greenwich mean time of transit on the 6th, gives 8*h.* 42*m.* for the mean time of transit at Baltimore.

On the 6th of December, by the Nautical Almanac, the

Right ascension at midnight was	1*h.*	40*m.*	48*s.*,	declination	7°	5′	34″	N
" " noon, "	1	12	56	"	4	53	36	N.
Increase in 12 hours from noon		27	52		2	11	58	

Then, 12*h.* : 27*m.* 52*s.* :: 8*h.* 42*m.* : 20*m.* 12*s.*, which added to the right ascension at noon gives 1*h.* 33*m.* 8*s.*, the moon's right ascension at 8*h.* 42*m.* when she passed the meridian of Baltimore. And 12*h.* : 2° 11′ 58″ :: 8*h.* 42*m.* : 1° 35′ 40″, which added to 4° 53′ 36″ N. the declination at noon, because increasing, gives 6° 29′ 16″ N., the declination when she passed the meridian. Hence, 90° — 39° 17′ + 6° 29′ 16″ = 57° 12′ 16″, the meridian altitude at the time proposed.

The places of the planets may be taken from the Nautical Almanac for noon, without material error, because they vary less than that of the moon.

ascension was 1 hour 33 minutes 8 seconds, and declination 6° 29′ 16″ N.; required her meridian altitude at Baltimore?

6. On the 1st of November, 1848, the right ascension of Venus was 16 hours 15 minutes, and declination 22° 4′ south; required her meridian altitude at Baltimore.

PROBLEM XVI.

The month, day, and hour of the day at any place being given, to find the altitude of any star, and its azimuth.

RULE.

Elevate the pole for the latitude of the given place, and screw the quadrant of altitude on the brass meridian over the degree of latitude; bring the sun's place in the ecliptic for the given day 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; 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; keep the globe from revolving on its axis, and move the quadrant of altitude, till its graduated edge comes over the given star; the degrees on the quadrant, comprehended between the horizon and the star, will be the altitude; and the degrees on the horizon, between the north or south point thereof and the quadrant, will be the azimuth.

EXAMPLES.

1. Required the altitude and azimuth of β in Leo, at Philadelphia, on the 20th of March at 10 o'clock in the evening?

Ans. The altitude is 59°, and azimuth 49½° from the south towards the east.

2. On what point of the compass does *Altair* bear at Washington, on the 19th of April, at 3 o'clock in the morning; and what is its altitude?

3. Required the altitude and azimuth of *Arcturus* at Dublin, on the 5th of September, at 8 o'clock in the evening ?

4. Required the altitude and azimuth of *Markab* in Pegasus, at Paris, on the 30th of August, at 9 o'clock in the evening ?

PROBLEM XVII.

The month and day of the month being given, and the altitude of a star at any place, to find the hour of the night, and the star's azimuth.*

RULE.

Elevate the pole for the latitude of the given place, and screw the quadrant of altitude on the brass meridian over the degree of latitude ; bring the sun's place in the ecliptic for the given day to the brass meridian, and set the index of the hour circle to 12 ; bring the quadrant to that side of the meridian† on which the star was situated when observed ; turn the globe westward on its axis, till the centre of the star cuts the given altitude on the quadrant ; then the hours passed over by the index will show the time from noon, when the star has the given altitude, and the degree on the horizon intersected by the quadrant, will be the azimuth.

EXAMPLES.

1. At Philadelphia, on the 20th of March, the star β in Leo, was observed to be 59° above the horizon, and east of the meridian, what hour was it, and what was the star's azimuth ?

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* If the observation be made in the morning, the hour can be as easily found by turning the globe eastward on its axis, and the number of hours passed over by the index will show the time from noon, in the morning, when the star has the given altitude.

† A star will have the same altitude on both sides of the meridian ; therefore, it is necessary to mention on which side of the meridian the star was situated at the time of observation.

Ans. It was ten o'clock in the evening, and the star's azimuth was 49½° from the south towards the east.

2. At Washington, on the 23d of October, the star *Lyra* was observed to be 52° above the horizon, and west of the meridian, what hour was it, and what was the star's azimuth ?

3. At Dublin, on the 11th of December, *Mirach* in Andromeda was observed to be 65° above the horizon, and east of the meridian, what hour was it, and what was the star's azimuth ?

4. At Baltimore, on the 1st of January, in the morning, the altitude of *Arcturus* was observed to be 44½°, and it was east of the meridian, what hour was it, and what was the star's azimuth ?

PROBLEM XVIII.

The month and day of the month being given, and the azimuth of a star at any place, to find the hour of the night, and the star's altitude.

RULE.

Elevate the pole for the latitude of the given place ; and screw the quadrant of altitude on the brass meridian over the degree of latitude ; bring the sun's place in the ecliptic for the given day to the brass meridian, and set the index of the hour circle to 12 ; bring the graduated edge of the quadrant to coincide with the given azimuth on the horizon, and keep it in that position ; then, turn the globe westward on its axis till the centre of the given star comes to the graduated edge of the quadrant, the hours passed over by the index will show the time from noon when the star has the given azimuth, and the degrees on the quadrant, comprehended between the horizon and the star, will be the altitude.

EXAMPLES.

1. At Philadelphia, on the 20th of March, the azimuth of β in Leo, was observed to be 49½° from the south towards the east, what hour was it, and what was the star's altitude ?

Ans. It was 10 o'clock in the evening, and the star's altitude was 59°.

2. At Washington, on the 23d of October, the azimuth of *Lyra* was 73° from the north towards the west, what hour was it, and what was the star's altitude?

3. At Dublin, on the 5th of September, the azimuth of *Arcturus* was 89° from the south towards the west, what hour was it, and what was the star's altitude?

4. At Paris, on the 30th of August, the azimuth of *Markab* in Pegasus was 66° from the south towards the east, what hour was it, and what was the star's altitude?

PROBLEM XIX.

The month and day of the month being given, and the hour when any known star rises or sets, to find the latitude of the place.

RULE.

Bring the sun's place in the ecliptic for the given day 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 as many hours as the time wants of noon; but, if the given time be past noon, turn the globe westward on its axis as many hours as the time is past noon; keep the globe from revolving on its axis, elevate or depress the pole till the centre of the given star coincides with the edge of the horizon, and the elevation of the pole will show the latitude required.

EXAMPLES.

1. In what latitude does *Menkar* in Cetus rise at 7 o'clock in the evening of the 21st of October?

Ans. 40° N.

2. In what latitude does *Arcturus* rise at 45 minutes past 8 o'clock in the morning, on the 21st of August?

3. In what latitude does *Alamak* in Andromeda, set at 3 o'clock in the morning, on the 16th of January?

4. In what latitude does *Alphecca*, in the Northern Crown, rise at 9 o'clock in the evening, on the 9th of February?

PROBLEM XX.

The meridian altitude of a known star being given, to find the latitude of the place of observation.

RULE.

Bring the centre of the given star to that part of the brass meridian which is numbered from the equinoctial towards the poles; count as many degrees on the brass meridian, from the star, either towards the north or south point of the horizon, according as the star was north or south of you when observed, as are equal to the given altitude, and mark where the reckoning ends; then elevate or depress the pole till this mark coincides with the north or south point of the horizon, and the elevation of the pole will show the latitude.

EXAMPLES.

1. In what latitude is the meridian altitude of *Aldebaran* in Taurus, 67¼° above the south point of the horizon?
Ans. 38° 53′ N.
2. In what latitude is the meridian altitude of *Arcturus*, 61½° above the south point of the horizon?
3. Being at sea on the 22d of August, 1848, I took the meridian altitude of *Altair*, and found it to be 56¼° above the south point of the horizon; required the latitude of the ship?
4. In what latitude is the meridian altitude of *Lyra* 80° above the north point of the horizon?

PROBLEM XXI.

The altitude of two known stars being given, to find the latitude of the place.

RULE.

Take the complement of the altitude of the first given star from the equinoctial in a pair of compasses, and, with one foot in the centre of that star, and a fine pencil in the other foot, describe an arc; take the complement of the altitude of the second star from the equinoctial as before, and, with one foot in the centre of this star, describe an arc to cross the former arc; 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 sought.

EXAMPLES.

1. In north latitude, I observed the altitude of *Capella* to be 30°, and that of *Castor* 48°; what latitude was I in?
Ans. 40° N.

2. At sea in north latitude, I observed the altitude of *Lyra* to be 35°, and that of *Altair* 25°; required the latitude in?

3. In north latitude, I observed the altitude of *Menkar* in Cetus to be 60°, and that of *Algenib* in Pegasus 35°; what was the latitude of the place of observation?

4. In north latitude, the altitude of *Procyon* was observed to be 40°, and that of *Bellatrix* in Orion, at the same time, was 64°; required the latitude of the place of observation?

PROBLEM XXII.

Two stars being given, the one on the meridian and the other on the eastern or western edge 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 revolving on its axis, and elevate or depress the pole till the entre of the other given star coincides with the eastern or western edge of the horizon; then the elevation of the pole will show the latitude.

EXAMPLES.

1. When *Lyra* was on the meridian, β in Leo was setting; required the latitude?
Ans. 35° N.

2. When *Markab* in Pegasus was on the meridian, *Castor* was rising; required the latitude?

3. When *Arcturus* was on the meridian, *Procyon* was setting; required the latitude?

4. In what latitude is β in Leo rising, when *Aldebaran* is on the meridian?

PROBLEM XXIII.

The latitude of a place, the day of the month, and two stars that have the same azimuth, being given, to find the hour of the night, and the common azimuth.

RULE.

Elevate the pole for 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 for the given day to the brass meridian, and set the index of the hour circle to 12; turn the globe westward on its axis, 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 degree of the horizon, intersected by the quadrant, will show the common azimuth.

EXAMPLES.

1. At what hour at Philadelphia, on the 10th of May, will *Arcturus*, and β in Libra, have the same azimuth, and what will that azimuth be?

Ans. At 10 o'clock in the evening, and the azimuth will be 36° from the south towards the east.

2. At what hour at Paris, on the 16th of August, will *Lyra* and *Altair* have the same azimuth, and what will that azimuth be?

3. On the 7th of September, what is the hour at Washington, when *Deneb* in Cygnus, and *Gemma* have the same azimuth, and what is the azimuth?

4. On the 19th of May, what is the hour at London, when *Dubhe* and *Capella* have the same azimuth, and what is the azimuth?

PROBLEM XXIV.

The latitude of a 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 for 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 for the given day to the brass meridian, and set the index of the hour circle to 12; turn the globe westward on its axis 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 show the time from noon when the two stars have that altitude.

EXAMPLES.

1. At what hour at New-York, on the 22d of August, will *Dubhe* and *Arcturus* have each 24° of altitude?

Ans. At 9 o'clock in the evening.

2. At what hour at Washington, on the 17th of February, will *Aldebaran* in Taurus, and *Betelguese* in Orion, have each 58° of altitude?

3. At what hour at Dublin, on the 22d of December, will *Procyon* and *Alioth* have each 28° of altitude?

4. At what hour at London, on the 16th of November, will *Algenib* in Pegasus, and *Algol* in Perseus, have each 51½° of altitude?

PROBLEM XXV.

To find on what day of the year, any given star passes the meridian of any place, at any given hour.

RULE.

Bring the given star 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 on its axis, 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 on its axis, till the index has passed over as many hours as the time is past noon; then, the degree of the ecliptic cut by the brass meridian, will show on the horizon the day of the month required.

EXAMPLES.

1. On what day of the month does *Arcturus* come to the meridian of Philadelphia, at 9 o'clock in the evening?

Ans. On the 7th of June.

2. On what day of the month, and in what month, does *Altair* come to the meridian of Washington, at 3 o'clock in the morning?

3. On what day of the month, and in what month does *Sirius* come to the meridian of Baltimore, at midnight?

4. On what day of the month, and in what month does *Procyon* come to the meridian of Greenwich, at noon?*

PROBLEM XXVI.

The day of the month and hour of the night or morning at any place being given, to find what planets will be visible at that hour.

RULE.

Elevate the pole for the latitude of the place, bring the sun's place in the ecliptic for the given day 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; but, if the given time be past noon, turn the globe westward on its axis till the index

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* When the given star comes to the meridian at noon, the sun's place will be found under the brass meridian, without turning the globe.

has passed over as many hours as the time is past noon; keep the globe from revolving on its axis, find the planets' places on the globe (by Prob. III. or IV.) and if any of their places be above the horizon, such planets will be visible at the given time and place.

EXAMPLES.

1. On the 28th of October, 1848, the right ascension of Venus, by the Nautical Almanac, was 15 hours 54 minutes, 11 seconds, and declination 20° 56′ 33″ S., was she visible at Washington at 6 o'clock in the evening?

Ans. Venus was a little above the western edge of the horizon, nearly in conjunction with β Scorpii.

2. On the 31st of December, 1848, the right ascensions and declinations of the planets were as follows; were any of them visible at New-York, at 9 o'clock in the evening?

	RIGHT ASCEN.	DECLIN.		RIGHT ASCEN.	DECLIN.
☿	18*h*. 22*m*. 24*s*.	24° 45′ 30″ S.	♃	9*h*. 37*m*. 24*s*.	15° 8′ 23″ N.
♀	21 29 10	16 46 43 S.	♄	23 26 18	5 58 58 S.
♂	17 0 17	23 0 41 S.	♅	1 8 40	6 37 49 N.
☽'s	23 39 29	3 9 52 S. at midnight.			

PROBLEM XXVII.

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, on any given day, at any given place.*

RULE.

Elevate the pole for the latitude of the place; then, if Venus be a morning star, bring the sun's place in the

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* When Venus' longitude is less than the sun's longitude, she rises before him in the morning, and is then called a morning star; but when her longitude is greater than the sun's longitude, she shines in the evening after him, and is then called an evening star.

ecliptic for the given day 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 the place of Venus on the globe for the given day (found by Prob. III. or IV.) 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. But, if Venus be an evening star, bring the sun's place to the western edge of the horizon, and set the index to 12; turn the globe westward on its axis till the place of Venus on the globe, comes to the western edge of the horizon, and the hours passed over by the index will show how long Venus sets after the sun.

NOTE.—The same rule will serve for Jupiter or Saturn, by finding his place on the globe instead of that of Venus.

EXAMPLES.

On the 11th of December, 1848, the right ascension of Venus was 19 hours 49 minutes 17 seconds, and declination 23° 4′ 55″ S.; was she an evening star, and if so, how long did she shine after the sun set at Washington?

Ans. Venus shone 2 hours and 30 minutes after the sun set.

2. On the 15th of May, 1848, the longitude of Venus was 36° 15′, and latitude 1° 24′ S., and of course a morning star; how long did she rise before the sun at Paris?

3. On the 1st of October, 1848, the right ascension of Jupiter was 9 hours 14 minutes 31 seconds, and declination 16° 36′ N., was he a morning star, and if so, how long did he rise before the sun at Philadelphia?

4. On the 18th of April, 1848, the right ascension of Jupiter was 6 hours 58 minutes 3 seconds, and declination 23° 7′ 7″ N., was he an evening star, and if so, how long did he shine after the sun set at Baltimore?

5. On the 1st of May, 1848, the right ascension of Saturn was 23 hours 33 minutes 25 seconds, and declination 4° 57′ 42″ S.; was he a morning or an evening star? If a morning star, how long did he rise before the sun at New-York; but if an evening star, how long did he shine after the sun set?

PROBLEM XXVIII.

To find what stars the moon can eclipse, or make a near approach to, or what stars lie in or near her path.

RULE.

Find the moon's longitude and latitude, or her right ascension and declination, for several days together, in the Nautical Almanac, and mark her places on the globe; (by Prob. III. or IV.) then lay the quadrant of altitude over these places, and you will see the moon's orbit, consequently, what stars lie in or near her path.

EXAMPLES.

1. What stars were in or near the moon's path on the 21st, 22d, 23d, 24th, 25th, and 26th of August, 1848? her right ascensions and declinations, at midnight, on these days, being as follows:

RIGHT ASCEN.	DECLINATION.	RIGHT ASCEN.	DECLINATION.
21st, 4*h*. 9*m*. 1*s*.	15° 56′ 22″ N.	24th, 7*h*. 3*m*. 32*s*.	17° 48′ 34″ N.
22d, 5 7 16	17 38 53 N.	25th, 8 0 1	16 19 13 N.
23d, 6 5 42	18 16 35 N.	26th, 8 54 37	13 57 17 N.

Ans. The stars will be found to be α Tauri, γ Geminorum, λ Geminorum, &c.

2. On the 16th, 17th, 18th, 19th, 20th, and 21st of December, 1848, what stars lay in or near the moon's path? her right ascensions and declinations at midnight, on these days being as follows:

RIGHT ASCEN.	DECLINATION.	RIGHT ASCEN.	DECLINATION.
16th, 11*h*. 23*m*. 22*s*.	4° 19′ 25″ N.	19th, 13*h*. 42*m*. 37*s*.	7° 7′ 58″ S
17th, 12 10 39	0 23 31 N.	20th, 14 28 38	10 28 54 S
18th, 12 56 49	3 28 10 S.	21st, 15 15 24	13 24 7 S

PROBLEM XXIX.

The day of the month being given, to find all those places on the earth to which the moon will be nearly vertical on that day.

RULE.

Find the moon's declination in the Nautical Almanac for the given day, and observe whether it be north or south; then, (by the terrestrial globe,) mark the moon's declination on that part of the brass meridian which is numbered from the equator towards the poles; turn the globe eastward on its axis, and all places that come under the above mark, will have the moon nearly* vertical on the given day.

EXAMPLES.

1. On the 10th of December, 1848, the moon's declination at midnight was 18° 29′ N., over what places on the earth did she pass nearly vertical?

Ans. The moon was nearly vertical at Port au Prince, Timbuctoo, Bombay, &c.

2. On the 27th of October, 1848, the moon's declination at midnight, was 12° 12′ S., over what places did she pass nearly vertical?

3. To what places of the earth will the moon be vertical, when she has the greatest† north declination?

4. To what places of the earth will the moon be vertical, when she has the greatest south declination?

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* On account of the swift motion of the moon in her orbit, and consequently, a considerable increase or decrease of declination in the course of 24 hours, the solution will differ materially from the truth.

† When the moon's ascending node is in Aries, she will have the greatest north and south declination; for her orbit making an angle of about 5¼° with the ecliptic, her greatest declination will be 5¼° more than the greatest declination of the sun.

PROBLEM XXX.

To find the time of the moon's southing, or coming to the meridian of any place, on any given day.

RULE.

Elevate the pole for the latitude of the place, find the moon's longitude and latitude, or her right ascension and declination, in the Nautical Almanac, for the given day, and mark her place on the globe; bring the sun's place in the ecliptic for the given day to the brass meridian, and set the index of the hour circle to 12; turn the globe westward on its axis 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 comes to the meridian of the place.

Or, *correctly, without the globe.* Take the difference between the sun and moon's increase of right ascension in 24 hours; then, as 24 hours less this difference, are to 24 hours, so is the moon's right ascension at noon less* the sun's right ascension at the same instant, to the time of the moon's passage over the meridian.

EXAMPLES.

1. At what hour on the 14th of June, 1848, did the moon pass over the meridian of Greenwich, her right ascension at noon being 15 hours 42 minutes 4 seconds, and her declination 15° 13′ S.

Ans. By the globe the moon came to the meridian at 10 minutes past 10 o'clock in the evening.

By Calculation.

Sun's right ascension at noon, 14th June,	5*h.*	31*m.*	33*s.*
" " " " 15th "	5	35	42
Increase in 24 hours, - -		4*m.*	9*s.*

* If the sun's right ascension be greater than the moon's, 24 hours must be added to the moon's right ascension before you subtract.

Moon's right ascension at noon, 14th June,	15*h.*	42*m.*	4*s.*
" " " " 15th "	16	31	40
Increase in 24 hours, - - -		49*m.*	36*s.*

Hence 49*m.* 36*s.* — 4*m.* 9*s.* = 45*m.* 27*s.*, the excess of the moon's motion in right ascension above the sun's in 24 hours. Then 24*h.* — 45*m.* 27*s.* : 24*h.* :: 15*h.* 42*m.* 4*s.* — 5*h.* 31*m.* 33*s.* : 10*h.* 30*m.*, the true time of the moon's passage over the meridian, agreeing with the Nautical Almanac.

2. At what hour, on the 16th of October, 1848, did the moon pass over the meridian of Greenwich; her right ascension at midnight being 5 hours 36 minutes, and her declination 18° 8′ N.?

3. At what hour on the 1st of September, 1848, did the moon pass over the meridian of Greenwich; her right ascension at noon, being 13 hours 23 minutes 10 seconds, and declination 5° 55′ S?

4. At what hour, on the 6th of December, 1848, did the moon pass over the meridian of Greenwich; her right ascension at noon being 1 hour 12 minutes 56 seconds, and declination 4° 54′ N.?

CHAPTER III.

MISCELLANEOUS EXAMPLES EXERCISING THE PROBLEMS ON THE GLOBES.

1. When it is 8 o'clock in the morning at Paris, what is the hour at Washington?

2. What is the sun's longitude and declination on the 17th of January?

3. How many miles make a degree of longitude in the latitude of Philadelphia?

4. When the sun is on the meridian of Philadelphia, what places have midnight?

5. What is the angle of position between London and Rome?

6. On what point of a compass must a ship steer from Cape Henry to Cape Clear?

7. What places of the earth have the sun vertical on the 13th of April?

8. What places of the earth are in perpetual darkness on the 18th of December? and how far does the sun shine over the south pole?

9. Where does the sun begin to shine constantly without setting on the 9th of May, and in what latitude is he beginning to be totally absent?

10. On what two days of the year will the sun be vertical at Bencoolen?

11. What is the length of the longest day at Washington?

12. What day of the year is of the same length as the 12th of May?

13. In what latitude does the sun set at 11 o'clock on the 1st of June?

14. How many days in the year does the sun rise and set in latitude 78° N.?

15. On what two days of the year at Philadelphia, is the time of the sun's rising to the time of his setting in the direct ratio of 4 to 3?

16. What day following the 4th of July is one hour shorter than it, at Baltimore?

17. What is the equation of time dependent on the obliquity of the ecliptic on the 1st of August?

18. On what day of the year is the meridian altitude of the sun at Washington equal to 45°?

19. At what hour will the sun be due east at Philadelphia on the 25th of May?

20. Being at sea on the 14th of June, I found the sun's setting amplitude to be 29° from the west towards the north; required the latitude the ship was in?

21. At what hour in the afternoon on the 2d of August, is the length of the shadow of any object at Washington equal to its height?

22. What is the sun's azimuth at New-York on the 30th of April, at 8 o'clock in the morning?

23. Required the duration of twilight at the north pole?

24. When the sun is setting to the inhabitants of Baltimore, to what inhabitants of the earth is he then rising?

25. What inhabitants of the earth have the greatest portion of moon light?

26. Required the latitude and longitude of *Dubhe*, in the back of the Great Bear?

27. What is the altitude of the north polar star at Mexico?

28. What is the hour at Paris, when a cane placed perpendicular to the horizon of Philadelphia on the 10th of June in the afternoon, casts a shadow equal to the length of the cane?

29. On the 1st of May, 1848, the geocentric longitude of Venus was 19° 10′, and latitude 1° 35′ S.; was she a morning or an evening star? If a morning star, how long did she rise before the sun at Washington; but if an evening star, how long did she shine after the sun set?

30. What inhabitants of the earth have no shadow on the 17th of May, when it is 40 minutes past 1 o'clock in the afternoon, at Philadelphia?

31. In what latitude is the meridian altitude of *Procycn* 57° above the south point of the horizon?

32. Being at sea in north latitude on the 5th of June, I observed the altitude of *Lyra* to be 49°, and that of *Altair* 21°; required the latitude in, and the hour of the night?

33. What stars never set at Washington, and what stars never rise at the same place?

34. How far northward must a person travel from Baltimore to lose sight of *Sirius?*

35. On what day of the month, and in what month, will the pointers* of the Great Bear be on the meridian of Washington at 10 o'clock in the evening?

36. When *Lyra* was on the meridian, I observed that *Spica* in Virgo was setting; required the latitude of the place of observation?

37. What is the sun's greatest meridian altitude at Paris?

38. What stars rise achronically at Washington, on the 11th of February?

39. What stars rise cosmically at Dublin, on the 2nd of May?

40. What stars set heliacally at London, on the 4th of July?

41. What stars set cosmically at Baltimore, on the 9th of October?

42. On what day of the year does *Aldebaran* rise achronically at Washington?

43. On what day of the year does *Procyon* begin to be visible in the evening at Washington?

44. On what day of the year does *Sirius* cease to appear in the evening at Baltimore?

45. At what time of the year does *Bellatrix* rise with the sun at New-York?

46. At what time of the year does *Sirius* become visible in the morning at Washington, after having been so near the sun as to be hid by the splendor of his rays?

47. At what time of the year does *Arcturus* first become invisible in the evening at Washington, on account of its nearness to the sun?

48. How long does β in Leo continue above the horizon, during one revolution of the earth on its axis, at Baltimore?

49. What is the distance in degrees between *Regulus* and *Dubhe?*

50. What are the sun's right ascension, oblique ascension, oblique descension, ascensional or descensional difference, rising

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* The two stars, marked α and β in the Great Bear, are called the pointers, because a line drawn through them, points to the polar star in the Little Bear; consequently they will both be on the meridian at the same time.

amplitude, setting amplitude, and the time of his rising and setting at Washington, on the 21st of June?

51. Required the Antœci of New-York?

52. Required the Periœci of Washington?

53. Required the Antipodes of O-why-hee?

54. Required the time of the moon's passage over the meridian of Greenwich, on the 31st of August, 1848; her right ascension being 12 hours 36 minutes 51 seconds, and declination 2° 13′ S.?

55. There is a place in latitude 19° 26′ N. which is 1770 geographical miles from Philadelphia, and west of it; required that place?

56. At what rate per hour are the inhabitants of Baltimore carried by the revolution of the earth on its axis from west to east?

57. What inhabitants of the earth have the days and nights always of equal length?

58. What is the length of the longest day in latitude 75° N.?

59. In what latitude north, is the length of the longest day 100 days?

60. On what day of the year does the sun set without rising for several revolutions of the earth on its axis, in latitude 73° N.?

61. How many days in the year does the sun rise and set in latitude 81° N.?

62. At what time does day break at Dublin, on the morning of the 1st of May?

63. What star has 11 signs 1° 15′ of longitude, and 21° 6′ S. latitude?

64. Being at sea in north latitude, I observed the altitude of *Capella* to be 37° 20′, and that of *Castor* at the same time, 53° 30′; required the latitude in?

65. Describe a horizontal dial for the latitude of New-York?

66. In what climate is Edinburg, and what other places are situated in the same climate?

67. What is the sun's altitude at Washington on the 31st of August, when the sun is setting at London?

68. Describe a vertical dial, facing the south, for the latitude of Washington.

69. In what latitude is the meridian altitude of Cor Hydræ 55° above the south point of the horizon?

70. Required the oblique ascension and descension of β in Leo, and its rising and setting amplitude, at Washington?

71. What is the breadth of the 10th north climate, and what places are situated within it?

72. What is the breadth of the 27th climate, or the 3d within the polar circles?

73. On the 7th of June, 1848, the sun's meridian altitude was observed to be 81° 20′ north of the observer; required the latitude?

74. On the 24th of April, in the afternoon, the sun's altitude was observed to be 58° 25′, and after $2\frac{3}{4}$ hours had elapsed, his altitude was 29° 10′; required the latitude, supposing it to be north?

75. Required the right ascension and declination of β in Lepus?

76. On the 25th of November, when it is 9 o'clock in the evening at Washington, what stars are culminating?

77. On the 1st of May, 1848, the right ascension of Jupiter was 7 hours 5 minutes 55 seconds, and his declination 22° 56′ N., was he a morning or an evening star? If a morning star, how long did he rise before the sun at Washington; but, if an evening star, how long did he shine after the sun set?

78. What is the meridian altitude of *Rigel* in the left foot of Orion, at Washington?

79. On what point of the compass does *Arcturus* bear at Washington, on the 21st of March, at 9 o'clock in the evening; and what is its altitude?

80. At London, on the 18th of October, the star *Capella* was observed to be 31° above the horizon, and east of the meridian; what was the hour at Washington at that time?

81. At what hour of the night at Washington, on the 15th of March, did *Regulus* bear S. E. by E.?

82. At what hour at Washington, on the 7th of December, will *Castor* and *Capella* have the same azimuth?

83. What inhabitants of the earth have noon, when day breaks at Washington, on the 17th of January?

84. At what hour at Washington, on the 8th of January, will *Rigel* and *Pollux*, have each 38° of altitude?

85. On the 10th of March, 1848, the moon's declination at midnight was 16° 28′ N., over what places on the earth did she pass nearly vertical?

86. In what latitude does the sun begin to shine constantly without setting, when the inhabitants of Mexico have no shadow at noon?

87. When the inhabitants of London begin to have constant day or twilight, what stars rise heliacally at Washington?

88. When the sun is on the meridian at Washington, at the time of the vernal equinox, what stars are rising at Canton?

89. When the sun sets without rising for several revolutions of the earth on its axis, at the North Cape, at what time does day break at Washington?

90. Are the clocks of Paris faster or slower than those at Washington, and how much?

91. What inhabitants of the earth have the sun vertical, when the *Pleiades* come to the meridian of Ispahan, at 8 o'clock in the evening?

92. What is the moon's longitude when new moon happens on the 24th of November?

93. What is the moon's longitude, when full moon happens on the 11th of September?

94. In what latitude is the length of the longest day, to the length of the shortest, in the ratio of two to one?

95. What is the length of the longest night, where the sun's least meridian altitude is 10°?

96. What is the length of the longest day, where the sun's greatest meridian altitude is 62°?

97. What is the altitude of the sun at Washington, when he is due west on the 10th of June?

98. At what hour does the sun rise at Washington, when constant day or twilight begins at Edinburg?

99. When *Aldebaran* rises with the sun at Washington, at what hour will *Altair* culminate at London?

100. Calculate the true time of the moon's passage over the meridian of Greenwich, on the 6th of December, 1848. The moon's right ascension at noon on the 6th of December was 1 hour 12 minutes 56 seconds, and on the 7th, at noon, it was 2 hours 9 minutes 18 seconds. The sun's right ascension at noon, on the 6th of December, was 16 hours 52 minutes 59 seconds, and on the 7th, at noon, it was 16 hours 57 minutes 22 seconds.

101. What is the length of the longest day at all places situated on the Arctic circle?

102. How many degrees must a person travel southward from Baltimore, that the north polar star may decrease 10° in altitude?

CHAPTER IV.

A TABLE OF THE LATITUDES AND LONGITUDES OF SOME OF THE PRINCIPAL PLACES IN THE WORLD.

The Longitudes are reckoned from the meridian of Greenwich Observatory.

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Aberdeen,	Scotland,	57° 9′ N.	2° 8′ W.
Abo,	Sweden,	60 27 N.	22 13 E.
Acapulco,	Mexico,	17 10 N.	101 26 W.
Achen,	Sumatra I.,	5 22 N.	95 35 E.
Adrianople,	Turkey,	41 10 N.	26 28 E.
Albany,	New-York,	42 39 N.	73 46 W.
Aleppo,	Syria,	36 11 N.	37 10 E.
Alexandretta,	Syria,	36 35 N.	36 15 E.
Alexandria,	Egypt,	31 12 N.	29 55 E.
Alexandria,	Virginia,	38 45 N.	77 16 W.
Algiers,	Africa,	36 49 N.	2 12 E.
Alicant,	Spain,	38 21 N.	0 30 W.
Amboy,	New-Jersey,	40 33 N.	74 20 W.
Amiens,	France,	49 54 N.	2 18 E.
Amsterdam,	Holland,	52 22 N.	4 53 E.
Annapolis,	Maryland,	39 2 N.	76 45 W
Antigua I.,	Caribbean Sea,	17 4 N.	62 9 W.
Antioch,	Syria,	35 55 N.	36 15 E.
Archangel,	Russia,	64 34 N.	38 55 E.
Ascension I.,	South Atlantic,	7 56 S.	14 21 W.
Athens,	Turkey, Europe,	38 5 N.	23 52 E
St. Augustine,	East Florida,	29 58 N.	81 40 W.
Babylon, (anc.)	Syria,	33 0 N.	42 46 E.
Bagdad,	Syria,	33 20 N.	44 23 E.
Baltimore,	Maryland,	39 17 N.	76 39 W.
Barcelona,	Spain,	41 26 N.	2 12 E.
Basil or Basle,	Switzerland,	47 34 N.	7 35 E.
Batavia,	Java I.,	6 11 S.	106 52 E.
Bayonne,	France,	43 29 N.	1 29 W.
Belfast,	Ireland,	54 43 N.	5 57 W.
Belgrade,	Turkey, E.,	45 0 N.	21 20 E.
Bencoolen,	Sumatra,	3 49 S.	102 3 E.
Bergen,	Norway,	60 24 N.	5 18 E.
Berlin,	Germany,	52 32 N.	13 23 E.

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Bermudas I. N.	Atlantic,	32° 35′ N.	64° 28′ W.
Berne,	Switzerland,	46 57 N.	7 26 E.
Bilboa,	Spain,	43 26 N.	2 47 W.
Bologna,	Italy,	44 30 N.	11 21 E.
Bologne,	France,	50 43 N.	1 36 E.
Bombay I.,	India, E.	18 56 N.	72 54 E.
Boston,	Massachusetts,	42 23 N.	71 0 W.
Botany Bay,	New-Holland,	34 0 S.	151 20 E.
Bourbon, I. N.,	Indian Ocean,	20 51 S.	55 30 E.
Bordeaux,	France,	44 50 N.	35 W.
Bremen,	Germany,	53 5 N.	8 49 E.
Brest,	France,	48 23 N.	4 30 E.
Bristol,	England,	51 28 N.	2 35 W.
Brunswick,	Germany,	52 25 N.	10 31 E.
Brunswick,	Maine,	43 52 N.	69 59 W.
Brunswick,	New-Jersey,	39 39 N.	74 18 W.
Brussels,	Netherlands,	50 51 N.	4 21 E.
Buenos Ayres,	South America,	34 35 S.	58 22 W.
Cadiz,	Spain,	36 31 N.	6 17 W.
Cagliari,	Sardinia I.,	39 25 N.	9 38 E.
Cairo,	Egypt,	30 3 N.	31 17 E.
Calais,	France,	50 57 N.	1 50 E.
Calcutta,	Bengal,	22 35 N.	88 28 E.
Cambridge,	England,	52 13 N.	5 E.
Cambridge,	Massachusetts,	42 23 N.	71 7 W.
Canary I.,	Canary Islands,	28 13 N.	15 39 W.
Candi,	Ceylon,	7 45 N.	80 46 E.
Candia,	Candy I.,	35 19 N.	25 18 E.
Canton,	China,	23 7 N.	113 16 E.
Cape Clear,	Ireland,	51 18 N.	9 30 W.
" Finisterre,	Spain,	42 53 N.	9 18 W.
" St. Vincent,	Portugal,	37 2 N.	9 2 W.
" Blanco,	Africa,	20 55 N.	17 10 W.
" Verd,	"	14 47 N.	17 33 W.
" Siera Leon,	"	8 30 N.	13 9 W.
" Good Hope,	"	34 29 S.	18 23 E.
" Comorin,	Hindoostan,	8 4 N.	77 34 E.
" Cod, (light,)	Massachusetts,	42 5 N.	70 14 W.
" Charles,	Virginia,	37 12 N.	76 9 W.
" Hatteras,	North Carolina,	35 12 N.	75 5 W.
" Horn,	South America,	55 58 S.	67 26 W.
" Blanco,	Peru,	3 45 S.	83 0 W.
" Farewell,	Greenland,	59 38 N.	42 42 W.
" Henry,	Virginia,	36 57 N.	76 19 W.
" May,	New-Jersey,	39 4 N.	74 54 W
Carthagena,	Spain,	37 37 N.	1 1 W.
Carthagena,	Terra Firma,	10 26 N.	75 21 W.
Charleston,	South Carolina,	32 50 N.	80 1 W.
Christiana,	Norway,	59 55 N.	10 48 E.
Conception,	South America,	36 43 S.	73 6 W.

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Constantinople,	Turkey,	41° 1′ N.	28° 55′ E.
Copenhagen,	Denmark,	55 41 N.	12 35 E.
Corinth,	Turkey,	37 54 N.	22 54 E.
Cork,	Ireland,	51 54 N.	8 28 W.
Cracow,	Poland,	50 11 N.	19 50 E.
Cusco,	Peru,	12 25 N.	73 35 W.
Damascus,	Syria,	33 16 N.	36 20 E.
Dardanelles,	Turkey,	30 10 N.	26 26 E.
St. Domingo,	Hispaniola,	18 20 N.	69 46 W.
Douglas,	Isle of Man,	54 7 N.	4 38 W.
Dover,	England,	51 8 N.	1 19 E.
Dresden,	Germany,	51 3 N.	13 41 E.
Drontheim,	Norway,	63 23 N.	10 22 E.
Dublin,	Ireland,	58 22 N.	6 17 W.
East Cape,	New-Zealand,	37 44 S.	178 58 E.
Eddystone light,	England,	50 7 N.	4 25 W.
Edinburg,	Scotland,	55 57 N.	3 12 W.
Exeter,	England,	50 44 N.	3 34 W.
False Cape,	Delaware,	38 88 N.	75 9 W.
Fayetteville,	North Carolina,	35 11 N.	78 50 W.
Fez,	Africa,	33 31 N.	5 0 W.
Florence,	Italy,	43 46 N.	11 2 E.
France, I.	Indian Ocean,	20 27 N.	57 15 E.
Francford on the Main,	Germany,	50 8 N.	8 35 E.
Funchal,	Madeira,	32 38 N.	16 56 W.
Galway,	Ireland,	53 10 N.	10 1 W.
Geneva,	Switzerland,	46 12 N.	6 8 E.
Genoa,	Italy,	44 25 N.	8 50 E.
Georgetown,	Columbia District,	38 55 N.	77 14 W.
St. George's town,	Bermudas I.,	32 22 N.	64 33 W.
Ghent,	Netherlands,	51 3 N.	3 43 E.
Gibraltar,	Spain,	36 5 N.	5 4 W.
Glasgow,	Scotland,	55 52 N.	4 15 W.
Goa,	Malabar,	15 28 N.	73 59 E.
Gottenburg,	Sweden,	57 42 N.	11 57 E.
Gottingen, (obs.)	Germany,	51 32 N.	9 54 E.
Greenwich, "	England,	51 28½N.	0 0
Guadaloupe,	West-Indies,	15 59 N.	61 59 W.
Hague,	Holland,	52 4 N.	4 17 E.
Halifax,	Nova Scotia,	44 44 N.	63 36 W.
Hamburg,	Germany,	53 34 N.	9 54 E.
Hanghoo,	China,	30 25 N.	120 12 E.
Hanover,	Germany,	52 22 N.	5 49 E.
Hartford,	Connecticut,	41 50 N.	72 35 W.
Havana,	Cuba I.,	23 12 N.	82 22 W.
Havre de Grace,	France,	49 29 N.	0 6 E.
St.Helena, Jamestown,	Atlantic,	15 55 S.	5 49 W.
Hervey's I.,	Society Isles,	19 17 S.	158 56 W.
Holyhead,	Wales,	53 23 N.	4 45 W.
Hull,	England,	53 48 N.	33 W.

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Jackson, (Port)	New-Holland,	33° 52′ S.	151° 14′ E.
Jaffa,	Syria,	32 5 N.	35 10 E.
St. Jago,	Cuba I.,	19 55 N.	75 35 W.
Ice Cape,	Nova Zembla,	75 30 N.	67 30 E.
Jeddo,	Japan I.,	36 30 N.	140 0 E.
Jersey I., St. Aubins,	English Channel,	49 13 N.	2 12 W.
Jerusalem,	Syria,	31 45 N.	35 20 E.
St. John's,	Newfoundland,	47 32 N.	52 26 W.
Ispahan,	Persia,	32 25 N.	52 50 E.
Isthmus of Darien joins	North and South America,		.
" Suez joins	Africa to Asia,		.
Kamtschatka,	Siberia,	56 30 N.	161 0 E.
Kilkenny,	Ireland,	52 37 N.	7 15 W.
Kingston,	Jamaica I.,	18 15 N.	76 44 W.
Kinsale,	Ireland,	51 32 N.	8 38 W.
Koningsberg,	Prussia,	54 43 N.	21 35 E.
Lancaster,	England,	54 4 N.	2 50 E.
Lancaster,	Pennsylvania,	40 3 N.	76 20 W.
Lands End,	England,	50 6 N.	5 54 W.
Leghorn,	Italy,	43 33 N.	10 16 E.
Lexington,	Kentucky,	37 59 N.	84 46 W.
Leyden,	United Provinces,	52 8 N.	4 28 E.
Lima,	Peru,	12 2 S.	76 50 W.
Limerick,	Ireland,	52 33 N.	8 42 W.
Lisbon,	Portugal,	38 42 N.	9 9 W.
Liverpool,	England,	53 22 N.	2 57 W.
Lizard,	"	49 57 N.	5 13 W.
London,	"	51 31 N.	6 W.
Londonderry,	Ireland,	54 59 N.	7 15 W.
Lyons,	France,	45 46 N.	4 49 E.
Madeira I., Funchal,	Atlantic,	32 38 N.	16 56 W.
Madras,	India,	13 5 N.	80 25 E.
Madrid,	Spain,	40 25 N.	3 38 W.
Majorca I.,	Mediterranean,	39 35 N.	2 30 E.
Malacca,	East India,	2 12 N.	102 9 E.
Malta I.,	Mediterranean,	35 54 N.	14 28 E.
Marietta,	Ohio,	39 8 N.	81 38 W.
Marseilles,	France,	43 18 N.	5 22 E.
Martinico I., Ft. Royal,	West Indies,	14 36 N.	61 10 W.
Mecca,	Arabia,	21 45 N.	40 15 E.
Mexico,	North America,	19 26 N.	100 7 W.
Milan,	Italy,	45 28 N.	9 14 E.
Minorca, Port Mahon.	Mediterranean,	39 51 N.	3 54 E.
Montpelier,	France,	43 37 N.	3 52 E.
Montreal,	Canada,	45 33 N.	73 18 W.
Morocco,	Barbary,	31 0 N.	7 4 W.
Moscow,	Russia,	55 45 N.	37 46 E.
Nankin,	China,	32 5 N.	118 46 E.
Nantes,	France,	47 13 N.	1 34 W.
Nantucket,	Nantucket I.,	41 18 N.	70 10 W

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Naples,	Italy,	40° 50′ N.	14° 17′ E.
Newcastle,	England,	55 3 N.	1 30 W.
New-Orleans,	Louisiana,	29 58 N.	90 6 W.
New-York,	New-York,	40 42 N.	74 1 W.
Niagara,	"	43 16 N.	79 0 W.
Norfolk,	Virginia,	36 55 N.	76 22 W.
North Cape,	Lapland,	71 30 N.	25 49 E.
Oporto,	Portugal,	41 10 N.	8 27 W.
L'Orient, (Port)	France,	47 45 N.	3 22 E.
Otaheite,	South Pacific Ocean,	17 20 S.	149 30 W.
O-why-hee,	North " "	18 54 N.	155 48 W.
Palermo,	Sicily I.,	38 7 N.	13 35 E.
Palmyra,	Arabia,	33 58 N.	38 42 E.
Panama,	Mexico,	8 58 N.	80 15 W.
Paris, (obsv.)	France,	48 50 N.	2 20 E.
Pekin,	China,	39 54 N.	116 27 E.
Pensacola,	West Florida,	30 30 N.	87 10 W.
Petersburg,	Russia,	59 56 N.	30 18 E.
Philadelphia,	Pennsylvania,	39 57 N.	75 11 W.
Pico I.,	Azores,	38 27 N.	28 28 W.
Pittsburg,	Pennsylvania,	40 26 N.	80 0 W.
Pondicherry,	East India,	11 56 N.	79 52 E.
Portland,	Maine,	43 39 N.	70 28 W.
Porto Bello,	Terra Firma,	9 33 N.	79 50 W.
Port Royal,	Jamaica,	18 0 N.	76 45 W.
Portsmouth,	England,	50 47 N.	1 6 W.
Potosi,	Peru,	20 0 S.	66 15 W.
Prague,	Bohemia,	50 6 N.	14 24 E.
Presburg,	Hungary,	48 8 N.	17 10 E.
Quebec,	Canada,	46 48 N.	71 6 W.
Quito,	Peru,	13 S.	78 10 W.
Rhodes,	Rhodes I.,	35 27 N.	28 45 E.
Richmond,	Virginia,	37 35 N.	77 43 W.
Riga,	Russia,	56 55 N.	24 0 E.
Rio Janeiro,	Brazil,	22 54 S.	42 44 W.
Rochelle,	France,	46 9 N.	1 10 W.
Rochester,	England,	51 26 N.	30 E.
Rome, (St. Peters,)	Italy,	41 54 N.	12 28 E.
Rotterdam,	United Provinces,	51 56 N.	4 28 E.
Rouen,	France,	49 27 N.	1 5 W.
Salonica,	Turkey,	40 41 N.	23 7 E.
Samarcand,	West Tartary,	39 35 N.	64 20 E.
Santa Cruz,	Teneriffe I.,	28 39 N.	16 22 W.
Santa Fe,	New-Mexico,	36 54 N.	104 30 W
Savannah,	Georgia,	32 4 N.	81 11 W.
Siam,	East India,	14 18 N.	100 49 E.
Smyrna,	Natolia,	38 28 N.	27 7 E.
Stockholm,	Sweden,	59 21 N.	18 4 E.
Suez,	Egypt,	29 50 N.	33 27 E.
Surinam,	South America,	6 30 N.	55 30 W

Names of Places.	*Country or Sea.*	*Latitudes.*	*Longitudes.*
Syracuse,	Sicily I.,	36° 53′ N.	15° 17′ E.
Teneriffe Peak,	Canary I.,	28 15 N.	16 45 W.
Tobolsk,	Siberia,	58 12 N.	68 19 E.
Tornea,	Lapland,	65 51 N.	24 14 E.
Toulon,	France,	43 7 N.	5 55 E.
Toulouse,	"	43 46 N.	1 26 E.
Trent,	Germany,	46 5 N.	11 6 E.
Trenton,	New-Jersey,	40 13 N.	74 50 W.
Trincomale,	Ceylon I.,	8 33 N.	81 21 E.
Tripoli,	Barbary,	32 54 N.	13 20 E.
Tunis,	"	36 16 N.	10 40 E.
Turin,	Italy,	45 5 N.	7 39 E.
Upsal,	Sweden,	59 52 N.	17 43 E.
Utretcht,	United Provinces,	52 5 N.	5 9 E.
Venice,	Italy,	45 27 N.	12 4 E.
Vera Cruz,	Mexico,	19 10 N.	97 20 W.
Versailles,	France,	48 48 N.	2 7 E.
Vienna, (obs.)	Austria,	48 12 N.	16 22 E.
Warsaw,	Poland,	52 16 N.	21 3 E.
Washington, (obs.)	North America,	38 53 N.	77 2 W.
Waterford,	Ireland,	52 12 N.	7 6 W.
Wexford,	"	52 22 N.	6 30 W.
Wyburg,	Russia,	60 55 N.	30 20 E.
York,	England,	53 59 N.	1 7 W.
Yorktown,	Virginia,	37 14 N.	76 36 W.
Zurich,	Switzerland,	47 22 N.	8 33 E.
Zutphen,	United Provinces,	52 12 N.	6 15 E.

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