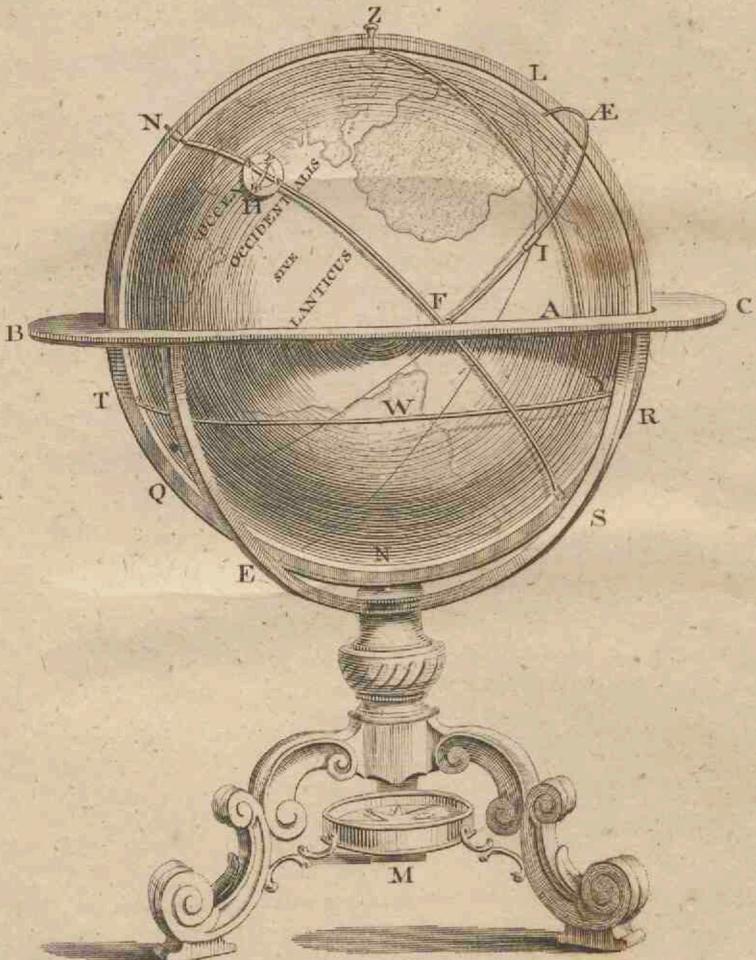
A treatise describing the construction and explaining the use of new celestial and terrestrial globes : designed to illustrate, in the most easy and natural manner, the phenomena of the earth and heavens, and to shew the correspondence of the two spheres ...

Plate I. *To Front the Title.*



The New

TERRESTRIAL GLOBE,

As Improved and Constructed by D. ADAMS

Fleet Street LONDON.

A TREATISE,

DESCRIBING THE CONSTRUCTION AND EXPLAINING THE USE OF

NEW CELESTIAL AND TERRESTRIAL

GLOBES;

Designed to illustrate,

IN THE MOST EASY AND NATURAL MANNER,

THE PHENOMENA OF THE EARTH AND HEAVENS,

AND TO SHEW THE

CORRESPONDENCE OF THE TWO SPHERES;

WITH A GREAT VARIETY OF

ASTRONOMICAL AND GEOGRAPHICAL

PROBLEMS.

By GEORGE ADAMS, Sen.

LONG DECEASED. FATHER TO THE LATE GEORGE ADAMS.

THE THIRTIETH EDITION.

In which a Comprehensive View of the Solar System is given; and the Use of the GLOBES is farther shewn, in the explanation of Spherical Triangles.

Now Published by

DUDLEY ADAMS,

GLOBE AND MATHEMATICAL INSTRUMENT MAKER TO HIS MAJESTY; OPTICIAN TO HIS R. H. THE PRINCE OF WALES, &c.; AND BROTHER TO THE LATE GEORGE ADAMS.

LONDON:

Printed for, and sold by the Publisher, No. 60, Fleet-street.

1810.

C. Baldwin, Printer,
New Bridge-street, London.

TO

THE KING.

SIR,

IT is the privilege of real greatness not to be afraid of diminution by condescending to the notice of little things; and I therefore can boldly solicit the patronage of your Majesty to the humble labours by which I have endeavoured to improve the instruments of science, and make the globes on which the earth and sky are delineated less defective in their construction, and less difficult in their use.

Geography is in a peculiar manner the science of princes. When a private student revolves the terraqueous globe, he beholds a succession of countries in which he has no more interest than in the imaginary regions of Jupiter and Saturn. But your Majesty must contemplate the scientific picture with other sentiments, and consider, as oceans and continents are rolling before you, how large a part of mankind is now waiting on your determinations, and may receive benefits or suffer evils, as your influence is extended or withdrawn.

The provinces which your Majesty's arms have added to your dominions make no inconsiderable part of the orb allotted to human beings. Your power is acknowledged by nations whose names we know not yet how to write, and whose boundaries we cannot yet describe. But your Majesty's lenity and beneficence give us reason to expect the time when science shall be advanced by the diffusion of happiness; when the desarts of America shall become pervious and safe, when those who are now restrained by fear shall be attracted by reverence, and multitudes who now range the woods for prey, and live at the mercy of winds and seasons, shall, by the paternal care of your Majesty, enjoy the plenty of cultivated lands, the pleasures of society, the security of law, and the light of Revelation.

I am,

SIR,

YOUR MAJESTY'S

most humble,

most obedient,

and most dutiful

Subject and Servant,

GEORGE ADAMS.

TO

THE PUBLIC.

DEEMING it proper to offer my reasons for reprinting this work *in its present shape*, I beg first to premise, that it has been my wish in this instance to give it according to the original text, *with the exception of a few notes*, that it may possess the merit of being the genuine production of my Father, viz. of George Adams, Sen.; who died in the year 1773. As a tribute due to his memory, it is but justice to say, that, for its plain unadorned language, perspicuity of definition, and copiousness of illustration, it has been rarely excelled, I believe never as an Elementary Treatise; in proof of which, it is only necessary to adduce the fact that even at this moment the work is sought after with as great avidity as formerly.

My Brother, the late George Adams, (who resigned his breath in the year 1795), treading in his Father's steps as an Author, reprinted and published *the same work* for many years, together with several of his own; by which he acquired the deserved approbation of a discriminating Public; and, such was his worth among a wide and extended circle of Friends, and in the scientific world, that his demise was considered a national loss. Having paid the debt of nature, his stock in trade, together with a valuable library (collected by my Father and himself during a period of 60 years), the copyrights of his own works, with those written by my Father also, were all sold by public auction. Over these and other events that occurred at this period, I will draw the veil, since to recapitulate them would neither be interesting nor useful to the Public, and would only serve to bring back to recollection circumstances that were not only unpleasant, but prejudicial and injurious to me; suffice it to say, that, from the respect I owed to the memory of my Brother, though I possessed at the time they were sold an inherent and exclusive right to all my Father's works, I offered no bar to, or in anywise prevented, the sale of them. *This work* was therefore disposed of among the rest, and falling into other hands, it passed through several editions. While it continued to be regularly reprinted as each edition was sold, and the Public and myself * suffered no disappointment from the want of it, I was perfectly indifferent as to who or what person was the Publisher; but when it became neglected, and was omitted to be published for nearly three years, I felt not only that I was called upon to publish it, but that to withhold it any longer from the Public would be to incur censure myself, which I trust I shall ever, as hitherto, have judgment enough to avoid. With the utmost deference therefore, I submit this work, the honest labour of my Parent, though long deceased, to a generous and discerning Public. If it were necessary to advance facts to prove the truth of my assertions with respect to my right to publish it, I have only to state that shortly after the decease of my Brother, I was put in possession of all my Father's manuscripts, which are numerous. They were the genuine and free gift of my Mother, and were accompanied with the original copper-plates, both for the work on the Globes, and that on the Microscope; the cuts therefore, that have been affixed to those two works, published by others for the last 15 years, will be found to be copies from my plates; and the Public will in their judgment decide as to their superiority or inferiority.

I may at some future time lay before the Public the original octavo work on the Microscope, † published also by my Father, with the plates, 60 in number, which have for many years

* I say myself, because it was particularly adapted to and written for Adams' Globes, which are manufactured by me.

† Intitled His Micrographia Illustrata, or the Microscope explained.

remained dormant in my closet; but for the present I shall content myself with publishing this work, and hope the price will be considered very moderate, not wishing so much to derive emolument from the work, as to give to it the greatest publicity possible.

I have prepared a Catalogue of Philosophical Instruments, of a far more detailed and descriptive kind than is usual, and comprising more articles than any other hitherto published, which I beg leave to offer also to the notice of the Public together with the work alluded to; and remain,

With the greatest respect,

Their devoted and most obedient Servant,

DUDLEY ADAMS.

FLEET-STREET,
Oct. 29, 1810.

PREFACE.

THE connection of astronomy with geography is so evident, and both in conjunction are so necessary to a learned education, that no man will be thought to have deserved ill of the republic of letters, who has applied his endeavours to throw any new light upon such useful sciences. And as the phœnomena of the earth and heavens can be adequately illustrated only by the mechanical contrivance of globes, whatever improvement is made in these must deserve regard, in proportion as it facilitates the attainment of astronomical and geographical knowledge. *

* Considerable improvements having been introduced into the construction of Adams's globes, it may not be improper to state in this place the ground on which the same was attempted. The Abbé Vinson, Professor of Astronomy, Teacher of the Globes, the Mathematics, &c. having for a considerable time admitted the great utility and superiority of the mode of mounting globes invented by my Father, constantly teaching thereon, in preference to any other construction, suggested to me the propriety (with a view to render them still more complete) of making several additions to the appendages of those globes. Suffice it to say, for the present, that with due attention to the object in view, and some perseverance in the execution of the various contrivances that were necessary to be made,

As to maps and all projections of the sphere *in plano*, their use is more difficult than those of the globe, of which indeed they are only so many pictures; nor can they be thoroughly understood without more skill in geometry than is commonly possessed by beginners, for whose use the following treatise is principally designed; though it also contains some observations, which I hope will not be altogether unacceptable to a more learned reader.

The globes now offered to the public, are of a construction new and peculiar; they are contrived to solve the various phœnomena of the earth and heavens in a more easy and natural manner than any hitherto published, and are so suspended that the student may elevate the south pole; a thing impracticable in the use of common globes.

That agreement too, which is here pointed out between the celestial and terrestrial sphere,

the same has been effected under my immediate instructions, and the globes thus newly mounted according to the Abbé Vinson's plan are respectfully submitted to the inspection of the public. They may be seen during the hours of business at my house, and the public are further informed that the Abbé is engaged in preparing a treatise thereon.

D. A.

will be found to open a large field of geographical and astronomical knowledge; and will afford both instruction and amusement to every unprejudiced inquirer. This correspondence arises from a comparison of one globe with the other, or of the distances of different places on the earth's surface, with the relative distances of such fixed stars as answer to them in the heavens.

By these steps of science, the mind of man may be raised to the contemplation of the divine wisdom, which has so adjusted the proportion of days, months, seasons, and years, in the different parts of the terraqueous globe, as to have distributed with an impartial hand, though after a manner wonderfully various, an equal share of the sun's light to every nation under heaven.

By these globes, with little or no experience in astronomy, may be seen how the moon changes her place every night, by observing her position with respect to any fixed star, and how she proceeds regularly from it to the eastward; as the several planets also may be observed to do, some more slowly than others, as their orbits are more or less remote from the center of the system; while the regularity of their motions, strictly conformable at all times to the laws of their Creator, exhibits a striking pattern of obedience to every rational spectator.

But it will be proper in this place to inform the reader what he is to expect in the globes, and in the following treatise intended to accompany and explain them.

The superior accuracy with which the plates are drawn and engraved will, it is hoped, appear to competent judges at the first sight; for the perfecting of which no expence of time or labour hath been spared. The celestial globe is improved by the addition of several thousand stars more than have appeared upon any globe hitherto published; all the latest discoveries in geography and astronomy are in both of them strictly followed, and many new lines and circles are inscribed, the use of which will be fully explained hereafter.

In the treatise, we have made choice of that method of finding the times of equinox, which is the most modern and simple; and which perhaps gives the truest mean length of a tropical year; that the young student may with greater ease and pleasure be made acquainted with the first principles, and from them be carried on to the more abstruse parts of astronomy.

To render this book as extensively useful as possible, I have endeavoured, with all the clearness I am master of, to express both my own and the sentiments of other authors on the same subject; and I think it my duty to acknowledge the assistance I have received in the course of this work, as well from books, as from some worthy friends; as I would not willingly incur the imputation either of plagiarism or ingratitude. If there should appear to be any defects, to which every human work is liable, the reader, I hope, will make some favourable allowance for the undertaker of a task so complicated and laborious, and correct my errors for himself as well as he is able.

N. B. When the reader is hereafter directed to apply a card, or the edge of a card, to any part of the globe, it is to be understood that he should cut a card of any kind, exactly in the size and shape of A B C D, fig. 4, for the globes of eighteen inches

fig. 27.

diameter; and of the size and shape of E F G H, for those of twelve inches diameter; then, if the arch B C, or F G, are applied to the surface of their respective globes, the lines A B, or C D, E F, and G H, will become radii from the center of the globe. It is frequently required to know what point upon the strong brass meridian, or broad paper circle, exactly answers to a given point upon the globe, and as this cannot be well known by inspection, on account of the necessary distance of these two circles from the surface, if the corner B or F be applied to the given point upon the globe, the edge of the card will exactly mark the degree or part of the degree required.

For elevating the pole exactly, the card is to be laid upon the broad paper circle, and its edge applied to the strong brass meridian, by which means the degree, and parts of a degree, may be ascertained with sufficient accuracy.

THE

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Plate 2.

The Copernican or

SOLAR SYSTEM.

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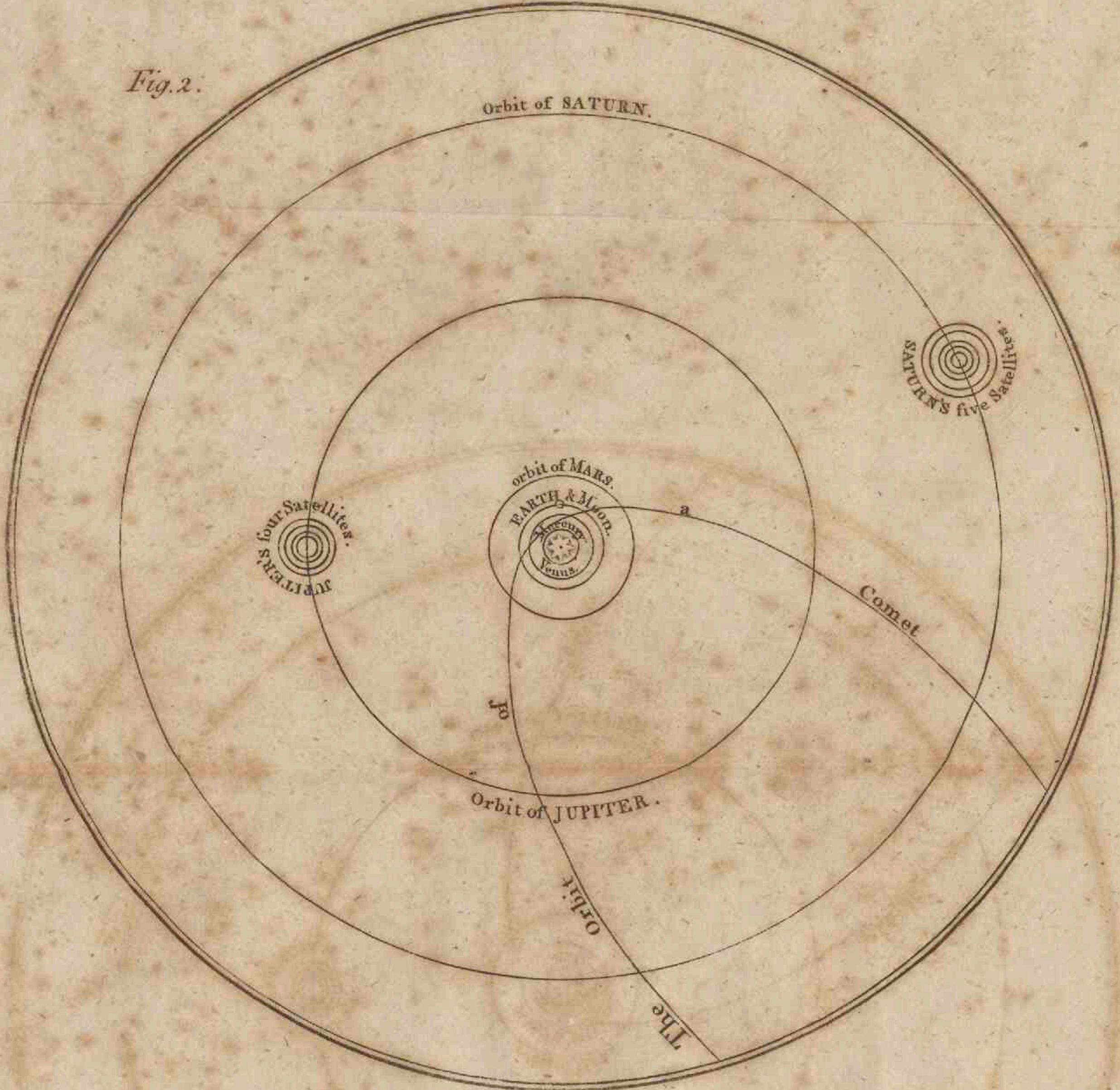
Fig. 2.



A

COMPREHENSIVE VIEW

OF THE

SOLAR SYSTEM.

ASTRONOMY, which is deservedly esteemed the most noble and exalted branch of human literature, regards the various phœnomena of those heavenly bodies, which the invention of curious instruments hath brought within our observation, from the surface of the terrestrial globe.

It discovers to us their situation, magnitudes, distances, and motions; and enables us to determine with precision the length of years, months, and days, and to account for the vicissitudes of the seasons; and, in a word, explains whatever falls within our consideration, as the proper subject of this useful and interesting study.

THE SOLAR SYSTEM

1. Consists of the sun, (from which it receives its denomination,) six primary, ten secondary planets, and the comets. These, with that collection of innumerable spherical bodies which compose the universe, are called the system of the world; all which appear to the inhabitants of the earth, as if they were within one and the same concave sphere.

2. The Copernican, or solar system, supposes the sun in the centre, having a motion round its axis, which is completed in about $25\frac{1}{4}$ days. This motion was discovered by the revolution of those spots which are frequently seen in its disc, and are supposed to adhere to its surface; and its axis is inclined to the plane of the ecliptic in an angle of about $87\frac{1}{4}$ degrees.

3. The six primary planets move round the sun in their respective elliptical orbits, from west to east, at different distances, and in various periodical times. Their names and characters, in the order in which they revolve about the sun, are expressed in fig. 2, and are as follow:

Mercury,	Venus,	The Earth,	Mars,	Jupiter,	Saturn.*
☿	♀	⊕	♂	♃	♄

4. The planets are distinguished from the fixed stars, by their motion, and the steadiness of their light. The apparent diameter of the fixed stars is so small, by reason of their immense distance, that every small atom floating in our atmosphere intercepts their light, and causes them to twinkle. But that of the planets being greater, as they are nearer to us, they shine with a steady light.

5. The fixed stars keep their places and distances

* Uranus, or the Georgian planet was discovered by Dr. Herschel in the year 1781. It had been seen by Flamsteed and other astronomers, but not distinguished from the fixed stars. It revolves round the sun in 81 years and 29 days. Its synodical revolution is 370 days. Its motion begins to be retrograde when, previous to the opposition, the planet is about 105° from the sun; its retrograde motion continues about 142 days, it is apparently stationary ten days, and its arc of retrogradation is about 4°.

Fig. 3.

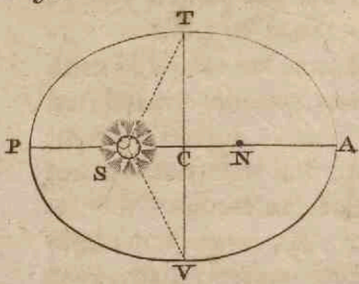


Fig. 4.

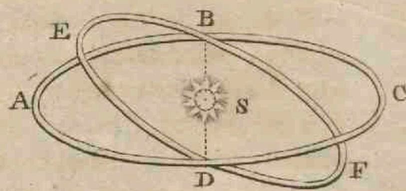


Fig. 5.

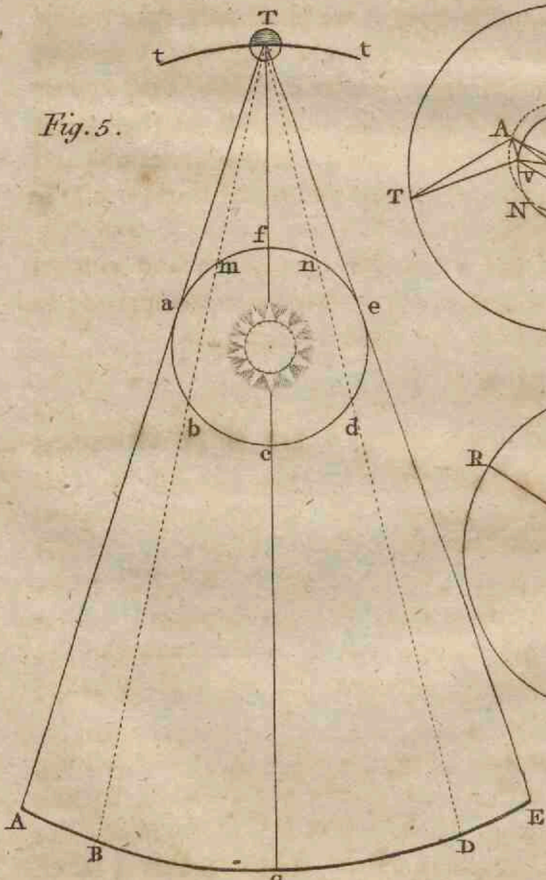


Fig. 6.

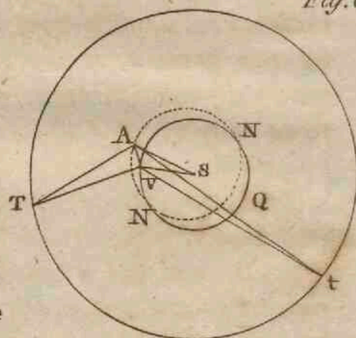
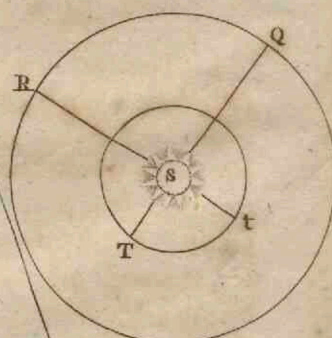


Fig. 7.



Goodnight sculp.

with respect to each other, but the planets change theirs from one part of the heavens to another.

6. Some of the primary planets are attended with smaller, called secondary planets, moons, or satellites. Our earth is attended by the moon; Jupiter by four, and Saturn by five satellites; the nine last are not visible without the assistance of a telescope.

7. The observation of comets, seen sometimes within the limits of the solar system, hath been hitherto so imperfect, that we shall only take notice for the present, that they are supposed to move round the sun, in very eccentric orbits, and appear to us only when they are in that part of their orbit nearest the sun: they move in various directions and inclinations; the lower part of one of these orbits is represented in fig. 2.

As the sun has a number of planets and comets moving round him, so every fixed star is supposed to be a sun, and to have a system of its own.

THE ORBITS OF THE PLANETS.

8. The path described by a planet in its motion round the sun is called its orbit. In fig. 2, their several orbits are represented by concentric circles: the paths which they describe are elliptical, and the sun is in one of the foci. In fig. 3, A T P V is an ellipse, A P its transverse, V T its conjugate diameter, S and N are its two foci, C is the centre of the ellipse; the distance between C S or C N is called the eccentricity.

9. The orbit of every planet is in a plane passing through the sun, which planes are inclined to one another: thus in fig. 4, let A B C D represent the earth's orbit, or plane of the ecliptic; this is taken

for a standard, from which the inclination of each orbit of the planets, as E D F B, is measured. The inclination of the orbit of Mercury is 7°, that of Venus 3° 24′, of Mars 1° 51′, of Jupiter 1° 19′, of Saturn 2° 30′.*

10. To a spectator from the sun, the planes of the orbit of each planet produced to the fixed stars would mark, in the celestial sphere, their several inclined heliocentric orbits; their passage through these is their heliocentric motion. These extended planes, to a spectator on the earth, mark out in the starry sphere their geocentric orbits; and their apparent motion through these, is called their geocentric motion.

11. The latitude of a planet seen from the earth, is called its geocentric, if seen from the sun, its heliocentric, latitude.

THE NODES OF A PLANET'S ORBIT

12. Are two points in which it intersects the plane of the ecliptic. In fig. 4, ABCD is the plane of the ecliptic; EBFD is the orbit of a planet, in which the points B and D are the two nodes. B the ascending, D the descending node; the point E is called its greatest northern, and F its greatest southern limit.

13. The line of the nodes is a line B D drawn through the sun from one node to the other.

A planet, seen from the earth, never appears in the ecliptic, but when it is in one of its nodes: in all other parts of its orbit it has geocentric latitude.

THE INFERIOR PLANETS

14. Are Mercury and Venus; they are called in-

* And of Herschel 0° 46′.

ferior, because their orbits are included within that of the earth ; see fig. 2.

MERCURY

15. Moves round the sun in 87 d. 23 h. 16 m. which is called his periodical time. If we call the mean distance of the earth from the sun 1000, the mean distance of mercury is 387, his eccentricity 80. No spots have yet been observed in Mercury ; therefore it is not certainly known whether he turns about his axis or not ; but it is most probable that he does.*

VENUS

16. Performs her revolution round the sun in 224 d. 16 h. 49 m. which is called her periodical time ; her mean distance is 724, and her eccentricity 5 ; her motion about her axis is performed in 24 d.† 8 h. according to Bianchini ; and the inclination of her axis to the plane of the ecliptic, is 15 deg.‡

17. The greatest distance of the earth, or of any planet from the sun, is called its aphelion or higher apsis ; its least distance is called the perihelion, or

* The orbit of Mercury being elliptical and more eccentric than any of the other planets, its distance from the sun is very variable, its greatest distance being 46,665, its least 30,754. Its orbit revolves in its own plane with a very slow motion, the point nearest the sun called the Perihelion moving 1° 57′ 20″ according to the order of the signs, in a century. The nodes, or points of its intersection with the ecliptic, move westward or contrary to the order of the signs 43″ in a year. Mercury is estimated to be a little more than one third as large as the earth.

† The magnitude and diurnal rotation of Venus are supposed to differ but little from those of the Earth.

‡ The line of the apsides of this planet, or greater axis of the ellipse, has a slow motion eastward of 2° 44′ 46″ in a century, and its nodes move in a contrary direction 31″ annually.

lower apsis. Thus in fig. 3, A is the place of the aphelion, P that of the perihelion. The axis P A of any planet's ellipsis is called the line of the apsides; the extreme points of its shortest diameter T V, are the places of its mean distance from the sun; and S T, or S V, the line of its mean distance.

18. A planet is said to be in conjunction with the sun, when its apparent place, seen from the earth, is in or near the sun's place; it is said to be in opposition, when the earth is between the sun and planet.

THE ELONGATION OF A PLANET

19. Is its apparent distance from the sun, as seen from the earth. A planet has no elongation when in conjunction with the sun; in opposition, it has 180 deg. In fig. 5, t T t represents a part of the earth's orbit; T the earth, S the sun; A C E an arch of the starry sphere, and d the place of Venus in her orbit. A spectator upon the earth at T would refer the sun's place to those fixed stars at C, and that of Venus to those at D; in this case the angle C T D is the apparent distance between the sun and Venus, and is called the angle of elongation.

20. An inferior planet may be in conjunction with the sun in two situations; first, when it is between the earth and the sun, called the inferior conjunction; second, when the sun is between the earth and planet, called its superior conjunction; but it can never be in opposition to the sun.

21. The greatest elongation of an inferior planet is when a line T E, drawn from the earth at T, through the planet at e, is a tangent to the orbit of the planet.

22. As an inferior planet moves from its greatest elongation at a, fig. 5, through c, its superior conjunction, to e, its greatest elongation on the other side of the sun, its geocentric motion is direct.

23. When the earth is at T, Venus at a, a spectator at T sees the planet at a, in the line T a A among the fixed stars at A: when the planet is come to b, it appears in the line T b B, or amongst the stars at B; at c, it is in its superior conjunction, and seen among the stars at C; at d, it appears among the stars at D; and when it arrives at e, it appears among those at E. In this motion, Venus appears to describe the arc A B C D E, in the concave sphere of the heavens: and as these letters are in the same direction with a b c d e, which express the planet's motion round the sun, its apparent motion seen from the earth is therefore direct, from west to east, or according to the order of the signs.

24. An inferior planet passing from e, its greatest elongation, through f, its inferior conjunction, to a, its greatest elongation on the other side of the sun, its geocentric motion is retrograde.

As Venus is moving from e to n, she appears in the line T n d D, and is seen among the stars at D; when she comes to f, her inferior conjunction, she appears amongst the stars at C; at m, she is seen in the concave sphere at B; and when she is at a, in her own orbit, she appears at A, in the heavens. Hence, as the planet passed through e n f m a, in its natural motion, its apparent motion was backwards, through E D C B A, or contrary to the order of the signs.

25. When the inferior planets are at their greatest elongation, they appear stationary, or continue in

the same place for some time, before their motion changes from direct to retrograde, or from retrograde to direct again.

The time of the retrogression of Venus is about 40 days, of Mercury, 18 days.

26 In order to have a clear idea of the apparent motion of a planet, conceive the lines T a A, T b B, &c. to move with the earth; so that the points e n f m a, whilst the earth performs its revolution, may run through the orbit of the planet.

27. The inclination of the orbits of the planets to the plane of the ecliptic is the cause why they do not seem to move in the ecliptic line, but are sometimes above, and at others below it. In fig. 6, let N V N Q be a circle in the plane of T t the ecliptic, and N A N, the planet's inclined orbit, S the sun, the earth at T, and the planet at A; if the short line V A be imagined perpendicular to the plane of the ecliptic, and to pass through the planet at A, the angle V T A, is the latitude of the planet, which is called the geocentric latitude, to distinguish it from the heliocentric latitude, as seen from the sun, which is represented by the angle A S V.

28. When a planet is in the node at N, it appears in the ecliptic line; as it recedes from thence its latitude increases; and this is different, according to the situation of the earth; so that the latitude is greater when the earth is at T, and the planet at A, than when the earth is at t, and the planet at V.

29. A planet is said to be in quadrature when it is 90 deg. distant from the sun; the inferior planets cannot be in quadrature, as their greatest elongation can never be a right angle; therefore they never appear far from the sun; for Venus and Mercury are

only seen in an evening towards the west, soon after sun-set, or a little before the sun rises in the morning. The greatest elongation of Mercury is 33 deg. and of Venus 48 deg.*

30. As Venus moves from her superior to her inferior conjunction, she sets after the sun, and is called the evening-star; and as she is moving from her inferior to her superior conjunction, she rises before the sun, and is called the morning-star.

31. The sun, being larger than any planet, enlightens a little more than an hemisphere; and as we can only see half a planet at once, that hemisphere which we see is called the disc of the planet. The inferior planets are not visible to us, when in their inferior conjunction, but their whole disc is illuminated in their superior conjunction: and when they are in one of their nodes, they appear on the disc of the sun like a black spot; and this is called a transit of the planet across the disc of the sun. As the enlightened hemispheres of the inferior planets are sometimes more, at others less turned towards the earth, they appear through a telescope to have all the phases of the moon.

32. When Venus is the evening-star, her horns are turned towards the east, and the sun sets before, and to the westward of her. When she is a morning-star, her horns are turned towards the west, and the sun rises after, or to the east of her; in both cases, the horns are always turned from the sun. When she is at her greatest elongation, half the enlightened hemisphere will face the earth, and her disc

* These greatest elongations vary much at different times, from the elliptic nature of the orbits; those of Mercury vary from 28° 40′ to 18°; those of Venus from 48° to 45°.

appears as the moon does in the quarters; but when in any part between that and her inferior conjunction, she appears horned, and between her greatest elongation and superior conjunction, her appearance is gibbous.

33. What has been said of the planet Venus, is also true with respect to Mercury, with this difference, that he is direct, stationary, &c. so much more frequently, as his revolutions round the sun are performed in a shorter space of time.*

THE EARTH.

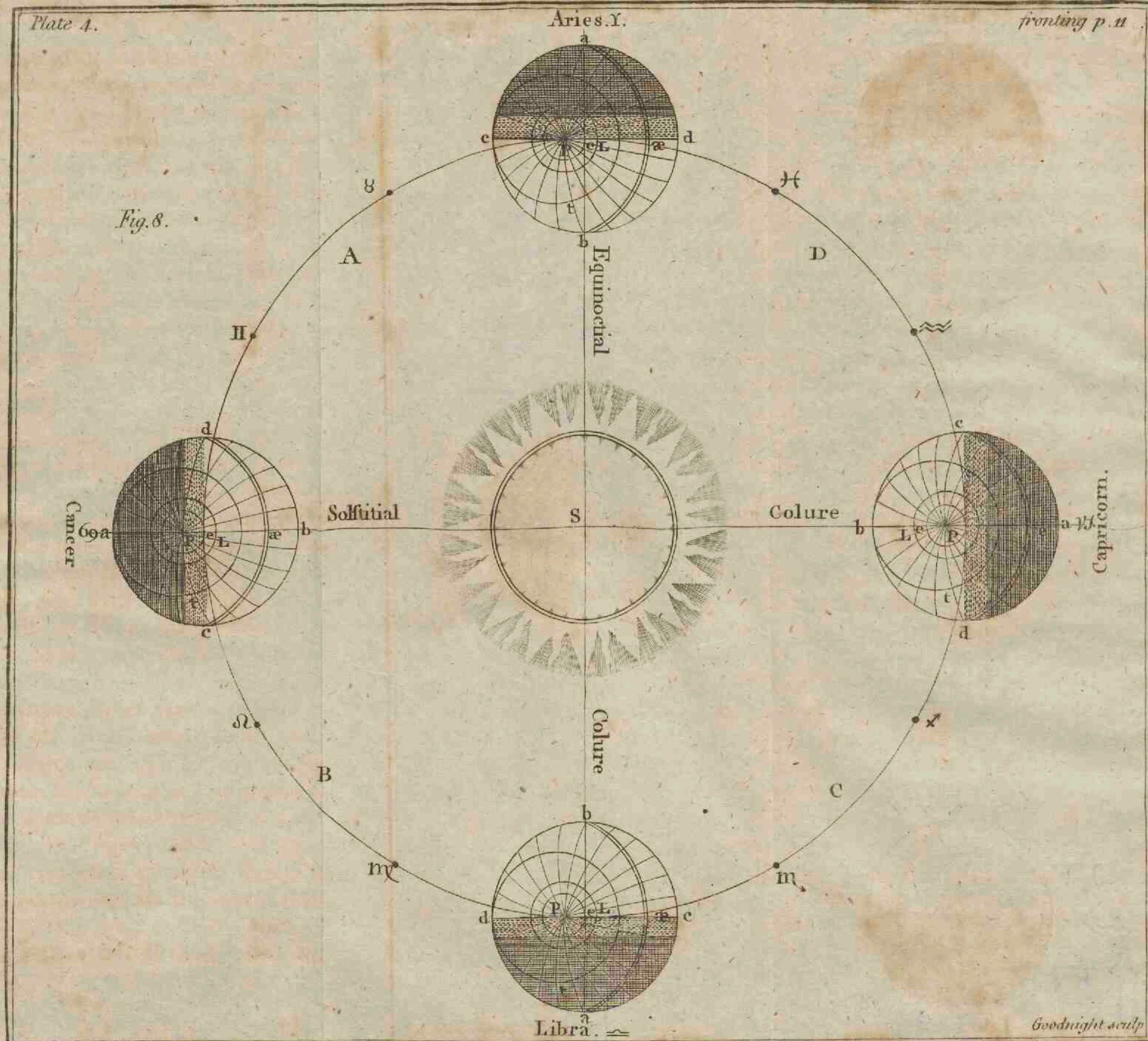
34. The apparent motion of the sun, arising from the earth's annual motion in its orbit, is as follows: In fig. 7, S represents the sun, T the earth in its orbit T t, and R Q the concave sphere of the fixed stars. Whilst the earth is moving in its orbit from T to t, the sun seems to move through the starry arch from Q to R, which measures the angle R S Q, equal to the angle T S t, so that the celerity of the apparent motion of the sun depends upon the celerity of the angular motion of the earth, with respect to the center of the sun. In a whole revolution of the earth, the sun also seems to run through a whole circle.

35. The earth moves round the sun between the orbits of Venus and Mars, in 365 d. 5 h. 49 m. Besides this annual motion, it turns round its own axis in 24 solar h.; its axis is constantly inclined in an

* The interval between two successive conjunctions of Mercury is about 115 d. of which 93 are progressive and 22 retrograde.

The interval between two conjunctions of Venus is about 584 days, during 542 of which her motion is progressive.

fronting p. 11



angle of 66½ deg. to the plane of the earth's orbit, or the ecliptic, and keeps continually parallel to itself in every part of its revolution.

In fig. 8, S represents the sun, A B C D the orbit of the earth; in the periphery of which, the centre of the earth is carried round the sun, according to the order of the signs, or in consequentia. ♈ S ♎ represents the equinoctial colure, ♋ S ♑, the solstitial colure; the circle in each, a b c d, represents the earth in the four cardinal points of its orbit; in which d c separates the enlightened part c b d of the earth's disc, from d a c, the obscure part of it.

The plane of the earth's annual orbit, A B C D, extended every way to the sphere of the fixed stars, would describe the celestial ecliptic, which would coincide with the terrestrial ecliptic, here represented by each of the circles a b c d; in which e, is the pole of the ecliptic, P the pole of the world, or of the equator: in all these projections, æ is the equator, t the tropic of Cancer, L the path or vertex of London; and the circles cutting each other in P, the pole of the world, are circles of right ascension in the celestial, and of longitude in the terrestrial sphere.

36. As the sun always enlightens one half of the earth's globe at the same time, the line d c, that divides the illuminated from the obscure part of the earth's disc, is called the edge of the disc.

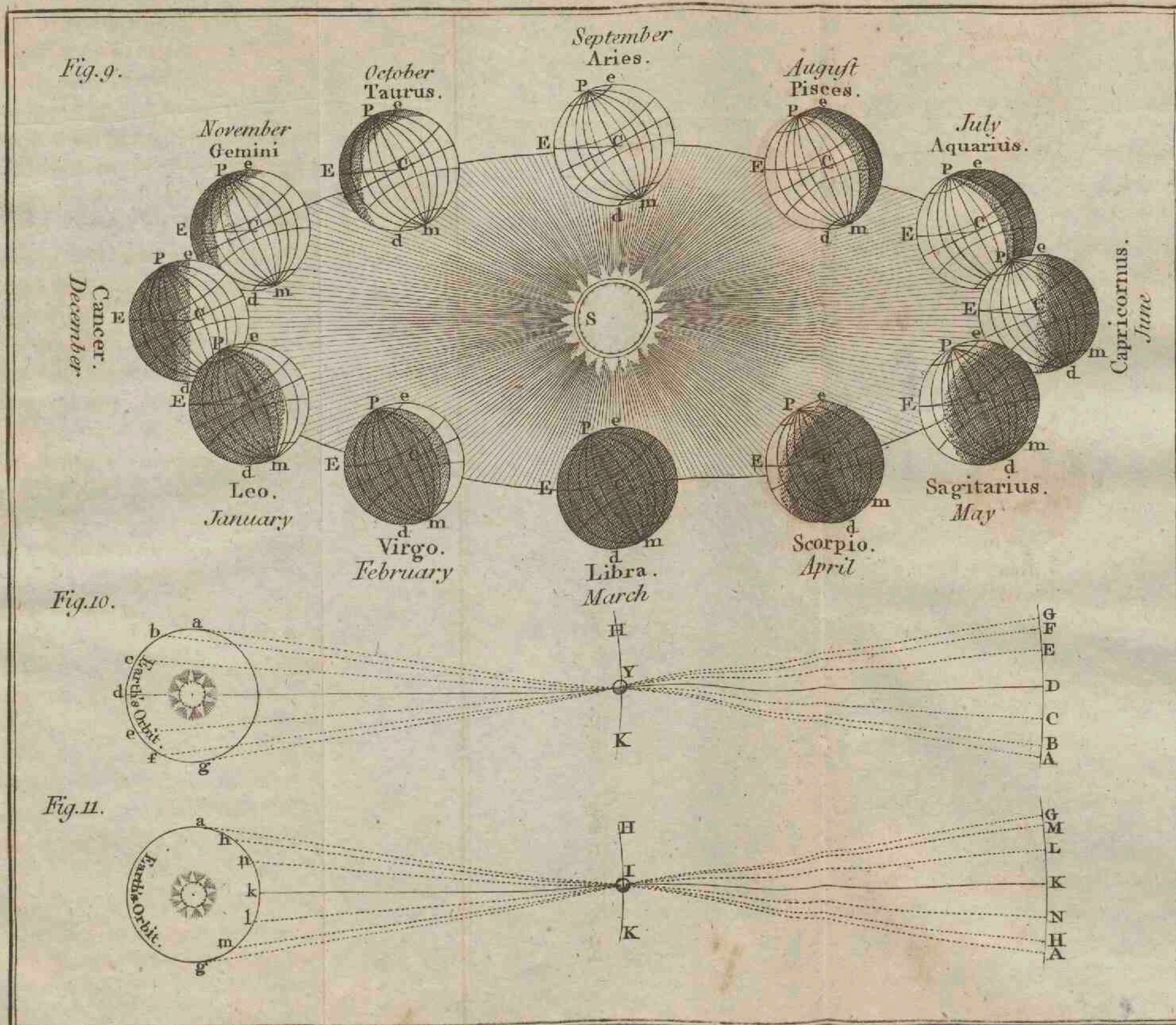
P a, P d, P b, P c, represent so much of the earth's axis as falls within these projections; these may be called the line of direction of the earth's axis, which is constantly carried round the annual orbit, always parallel to itself.

37. The inclination of the earth's axis will be

better understood by observing fig. 9, in which A B C D represents the earth's orbit, seen at a distance; the eye supposed to be elevated a little above the plane of it. The earth is here represented in the first point of each of the twelve signs, as marked in the figure, with the twelve months annexed: e the pole, and e d the axis of the ecliptic, always perpendicular to the plane of the orbit. P the north pole of the world, P m its axis, about which the earth's daily motion is made from west to east. P C E shews the angle of its inclination, which preserves its parallelism through every part of its orbit.

38. When the earth is in the first point of Libra, the sun then appears in the opposite point of the ecliptic at Aries, about the 22d of September, N. S. and when the earth is in Aries, the sun will then appear in Libra about the 19th of March; at which time of the year the edge of the enlightened hemisphere is parallel to the solstitial colure, fig. 8, and passes through the two poles of the world, dividing every parallel to the equator into two equal parts; whence the diurnal parallel of every inhabitant on the surface of the earth will, at either of these seasons, be half in the illuminated, and half in the obscure part of the earth; consequently the day and night will be equal in all places.

39. Conceive the earth to have moved from ♎ Libra to ♑ Capricorn, its line of direction keeping its parallelism will now coincide with the solstitial colure, fig. 8, and the edge of the disc will be perpendicular thereto, and pass through e, the pole of the ecliptic. In this situation of the earth, all places within the northern polar circle are illuminated



Goodnight sculp

throughout the whole diurnal revolution; at which time their inhabitants see the sun longer than 24 h.; but those which lie under the polar circle touch the edge of the disc, and therefore their inhabitants only see the sun skim quite round their horizon at its first appearance; every other parallel intersects the edge of the disc; and as the illuminated part of each is much greater than the obscure part, the days are consequently at this season, of the summer solstice, which happens about the 21st of June, longer than the nights. While the earth is moving from Libra, through Capricorn to Aries, the north pole P, being in the illuminated hemisphere, will have six months continual day; but while the earth passes from Aries through Cancer to Libra, the north pole will be in the obscure part, and have continual night; the south pole of the globe at the same time enjoying continual day.

40. When the earth is at Cancer, the sun appears at Capricorn. At this season the nights will as much exceed the days, as the days exceed the nights, when the earth was in the opposite point of her orbit; for the nocturnal arches, or obscure part of their paths, are here equal to the illuminated parts, when the earth was at Capricorn; and the illuminated part is here no more than the obscure part was in that place.

OUR SUMMER IS NEARLY EIGHT DAYS LONGER THAN THE WINTER.

41. By summer, is meant the time in which the earth is moving in her orbit from the vernal to the autumnal equinox; and by winter, the time in which

it is passing from the autumnal to the vernal equinox. Upon the globe it is evident that the ecliptic is divided into six northern and six southern signs, and that it intersects the equator at the points marked ♈ and ♎. In our summer, the sun's apparent motion is through the six northern, and in winter through the six southern signs; yet the sun is 186 d. 11 h. 51 m. in passing through the six first, and only 178 d. 17 h. 58 m. in passing through the six last. Their difference 7 d. 17 h. 53 m. is the length of time by which our summer exceeds the winter.

42. In fig. 16, A B C D represents the earth's orbit; S the sun in one of its foci: when the earth is at B, the sun appears at H in the first point of Aries; and whilst the earth moves from B, through C to D, the sun appears to run through the six northern signs, ♈ ♉ ♊ ♋ ♌ ♏ to ♎ at F. When the earth is at D, the sun appears at F in the first point of Libra; and as the earth moves from D through A to B, the sun appears to run through the six southern signs, ♎ ♍ ♐ ♑ ♒ ♓ to Aries at H. Hence the line F H, drawn from the first point of ♈, through the sun at S, to the first point of ♎, divides the ecliptic into two equal parts; but the same line divides the earth's elliptical orbit A B C D into two unequal parts, (the sun not being in the centre, but in one of the foci of this orbit;) the greater part B C D, is that which the earth describes in summer, whilst the sun appears in the northern signs; the lesser part is D A B, which the earth describes in winter, whilst the sun appears in the southern signs. C, the earth's aphelion, where it moves the slowest, is in the greater part; A, its

perihelion, is in the lesser part, where the earth moves fastest.*

43. The sun's apparent diameter is greater in our winter than in summer, caused by the earth being nearer to the sun, when in its perihelion at A in winter, than it is in the summer, when in its aphelion at C; which is its greatest distance. The sun's apparent diameter in winter is 32 m. 47 sec., in summer 31 m. 40 sec.

If the mean distance of the earth from the sun be called 1000, its eccentricity will be 17; its greatest distance 1017, and its least distance 983.

THE SUPERIOR PLANETS.

44. The apparent motions of the superior planets

* We thus see the reason why the seasons are of unequal length; for the summer and winter months can never be equally divided but in the particular case of the coincidence of the perihelion of the earth's orbit with one or other of the equinoxes. The perihelion does not remain stationary when once determined, but has a progressive motion in the ecliptic according to the order of the signs, performing a complete revolution in about 20,000 years. It is a remarkable circumstance that this coincid nce of the perihelion and aphelion, with the equinoctial points, took place about the period at which chronologists place the creation of the world, or about 4000 years before the christian æra: in consequence of this, the heat and light of the sun was then equally divided between the two hemispheres of the terrestrial globe, but as the perigee continued to advance on the ecliptic, the northern hemisphere gradually obtained the greatest share, and about the year 1250 the difference was a maximum, since that period it has continued to diminish by insensible degrees, and will do so till the year 6470, when a perfect equality will again subsist between the two hemispheres, after which the southern hemisphere will obtain the advantage of having the greater share of the heat of the sun, which advantage it will continue to possess for a similar period of 10,000 years.

agree in many respects with those of the inferior ones, which have been already explained.

MARS, JUPITER, AND SATURN,

Are called superior planets. See fig. 2.

45. If the mean distance of the earth from the sun be called 1000, the mean distance of Mars is 1523,* its periodical time 686 d. 23 h., its eccentricity 141, and it turns round its axis in 24 h. 40 m. The planet Mars appears much larger and brighter when it is in opposition to the sun, than when it is in conjunction with him.† Mars appears gibbous, when it is in quadrature, but full and round in conjunction or opposition.

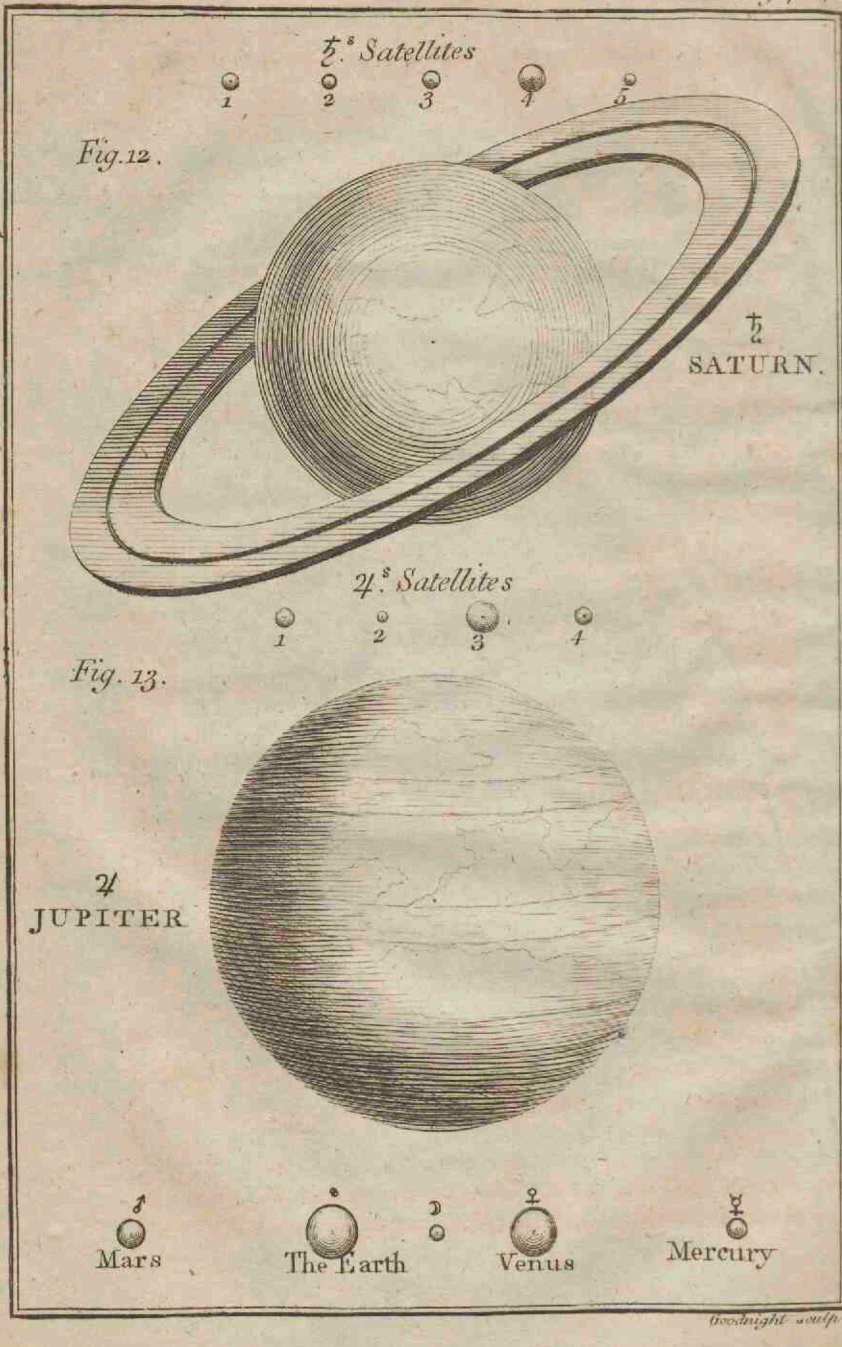
46. Jupiter is the largest of all the planets, see fig. 13, he revolves in 9 h. 56 m. about his axis, which is nearly at right angles to the plane of his orbit, in which he moves about the sun in somewhat less than 12 years, or 4332 d. 12 h. His mean distance from the sun is 5201, and eccentricity 250. Several spots have been seen on Jupiter's surface, which appears to be surrounded by several belts, or girdles, parallel to his equator: these vary in breadth and distance from one another. See fig. 13.

47. Saturn is the farthest of all the planets from the sun; his mean distance is 9538, eccentricity 547; he is 29½ years in moving through his orbit round the sun, or 10759 d. 7 h.‡ It is not yet known

* The time of its synodical revolution or period between two oppositions is 780 d. of which it is 707 d. progressive, and 73 retrograde; its arc of retrogradation varies from 10° to 18°.

† The diameter of Mars is about half that of the earth.

‡ It is the opinion of Dr. Herschel that Saturn revolves on its axis in 10 h. 16 m., and that its ring revolves in 10 h. 32 m.; the ring is likewise now known to be double or to consist of two concentric rings.



Goodnight sculp.

whether Saturn turns round his axis or not; but he is attended with a broad thin ring, as represented in fig. 12. The edge of this ring reflects little or none of the sun's light to us: the planes of it reflect the light of the sun in the same manner in which the planet does. The plane of the ring is inclined to the plane of the ecliptic at an angle of about 31 deg. If we suppose the diameter of Saturn to be divided into four equal parts, the diameter of the ring will be about nine such parts. The distance of the inner edge of this ring, from the body of the planet, is equal to the breadth of the ring. Through this space, between the planet and his ring, the fixed stars may sometimes be seen.

48. The plane of Saturn's ring is parallel to itself in every part of its orbit. If the plane of the ring be produced to the sphere of the fixed stars, it will cut Saturn's heliocentric orbit in two opposite points, called *the nodes of the ring*. As Saturn passes from the ascending to the descending node of his ring, the northern side of the plane of the ring is turned towards the sun; as it moves from the descending to the ascending node of the ring, the southern side of its plane is towards the sun. When Saturn's ring appears elliptical, as in fig. 12, the parts about its longest axis reaching beyond the planet's disc, are called *ansæ*, which a little before and after the disappearance of the ring, are unequal in magnitude. When Saturn is in the heliocentric place of either of the nodes of his ring, its plane produced passes through the sun, and then the ring becomes invisible to us.*

* The ring may likewise disappear from two other causes: its plane may pass through the place of a spectator on the earth, when,

The superior planets are sometimes in conjunction with the sun, sometimes in quadrature, and sometimes in opposition.

49. When the earth is in such a station, that a line drawn from a superior planet to the earth becomes a tangent to the earth's orbit, the superior planet appears stationary. If the earth be at a or g, fig. 10, or 11, and the planet at I; I g, and I a, are tangents to the earth's orbit; in which places the planet seems to stand still, or to have no geocentric motion.

50. When a superior planet, fig. 10, is moving from one of its apparent stations A, through its conjunction D to G, its geocentric motion is direct.

Fig. 10. Whilst the earth is moving from a, through d to g, a superior planet at I appears to move in ADG, the concave sphere of the heavens, from A, through its conjunction D, to its other station G; whence its apparent motion seen from the earth is direct, or *in consequentia*, which is from west to east, according to the order of the signs.

51. Observe in fig. 10, that one end a, of the line a I A, drawn from the earth at a, through the planet's place at I, to the concave starry sphere A D G, attends the earth, as it moves through a b c d e f g; and the middle of it is supposed to turn round upon the planet as a centre at I, the other end A will then mark out the planet's apparent motion in the heavens. So that the arch A B C D E F G, will be that which

the edge only being presented, it will not be visible except in the powerful telescopes of Dr. Herschel. Sometimes the plane of the ring passes between the sun and the earth, when the dark part is turned towards the earth and of course invisible; their combinations produce a curious succession of appearances and disappearances, for a full account of which the reader is referred to astronomical writers.

the planet appears to describe; and therefore the order of the letters expresses its motion *in consequentia.*

52. When a superior planet is passing from one station to the other through the opposition, its geocentric motion is retrograde.

As the earth is passing from g, fig. 11, through k to a, the planet at I appears to move from G, through K its opposition, to A; in this case, the apparent motion of the planet at I, seen from the earth, is retrograde, or *in antecedentia*, that is, from east to west, or contrary to the order of the signs. If the end g of the line g I G, fig. 11, attends the earth through g m l k n h a, and the middle of this line turns round upon the planet at I, the other end G will describe the arch G M L K N H A, which is contrary to the order of the letters in fig. 10, and therefore retrograde.

53. The time of the retrogression of Mars is about 3 months; of Jupiter 4 months; and of Saturn $4\frac{1}{2}$ months.

The planets viewed through a telescope are stripped of their adventitious rays, and appear like circular planes, of a determinate magnitude, whose diameters may be measured by a micrometer.

54. The superior planets are sometimes nearer our earth than at other times; whence they appear larger or less, according to their different distances from us. And as they are nearer to us than the fixed stars, they may pass between us and some of the stars: and as they go round the sun in orbits larger than that of the earth, they always turn much the greatest part of their illuminated hemisphere towards the earth, and therefore appear at all times round, or full,

except only Mars, which in the quadratures is a little gibbous *.

* It may be observed as a general rule, that the planets move slower in describing their retrograde arcs than when they are progressive, and their apparent magnitudes are then likewise greater; but there is this difference in the inferior and superior planets, that in the former, the planet is always in conjunction with the sun in the middle of the retrograde arc; and in the latter, they are always in opposition. In the middle of their progressive arcs they are universally in conjunction with the sun, and in the case of an inferior planet, this is called the superior conjunction.—The farther a superior planet is from the sun, the smaller is its arc of retrogradation, but the greater number of days it employs to describe it: thus the arc of retrogradation of Uranus is only 4°, while that of Jupiter is 10°; but Jupiter describes this arc of 10° in 120 days, whereas Uranus employs 142 days in describing the retrograde arc of 4°.

OF THE NEW PLANETS, CERES, PALLAS, JUNO, AND VESTA.

Astronomers had long observed that a greater interval existed between the orbits of Mars and Jupiter, than suited the apparent regularity of the system; but as no theory suggested any absolute necessity for this space to be occupied by a revolving body, not much importance was ever attached to this circumstance. It is now found that this space is occupied by a number of smaller bodies, which appear to be much less even than the smallest satellites of the system. These bodies all revolve at nearly the same mean distance from the sun, (namely, about 250 millions of miles,) and in orbits very considerably inclined to each other, and to the ecliptic. The diameter of the largest of them does not exceed 200 miles, and some are estimated by Dr. Herschel much less; they have likewise a nebulous, indistinct appearance, like comets. This and some other circumstances induced Mr. Olbers to conjecture, that these bodies were only fragments of a large planet which once revolved in an orbit now common to them all, and that this original planet has been broken to pieces by some internal explosion of the nature of our volcanoes.—Ceres was discovered by Piazzi, at Palermo, June 1, 1801; Pallas by Olbers, March 28, 1802; Juno by Harding, Sept. 1, 1804; Vesta by Olbers, March 29, 1807.

THE SECONDARY PLANETS.

55. Three of the primary planets, viz. the Earth, Jupiter, and Saturn *, in their revolutions round the sun, are attended with lesser planets, which move round each of their respective primaries, according to the order of the signs.

THE MOON

56. Moves round the earth in an orbit, whose semidiameter is about 60¼ semidiameters of the earth; its eccentricity 3⅓ of the earth's semidiameters; the plane of the earth's orbit, produced to cut the plane of the ecliptic, makes an angle with it of about 5½ deg. The points wherein it intersects the ecliptic are called the moon's nodes; these nodes have a slow regressive motion of 19° 19′ 43″ in a year, which carries them round the ecliptic, contrary to the order of the signs, in 18 y. 234 d. The moon's periodical time is 27 d. 7 h. 43 m. and her rotation round her axis is performed in the same time.† Her

* To which may now be added Uranus, or the Georgian.

† The moon, independently of its phases, will present nearly the same phenomena in a month, as the sun is observed to do in the course of a year: twice in the month she will be in the equator, and will then rise in the east, set in the west, and continue twelve hours above the horizon; when at its greatest declination south its meridian altitude will be less than that of the equator by the whole of its declination, it will rise south of the east, and its continuance above the horizon will be much less than twelve hours, sometimes only seven, its diurnal course resembling that of the sun on the shortest day; on the contrary, when it has arrived at its greatest distance north, its meridian altitude greatly exceeds that of the equator, it rises to the north of the east, and continues nearly seventeen hours above the horizon, its diurnal path nearly resembling that of the sun on the longest day.

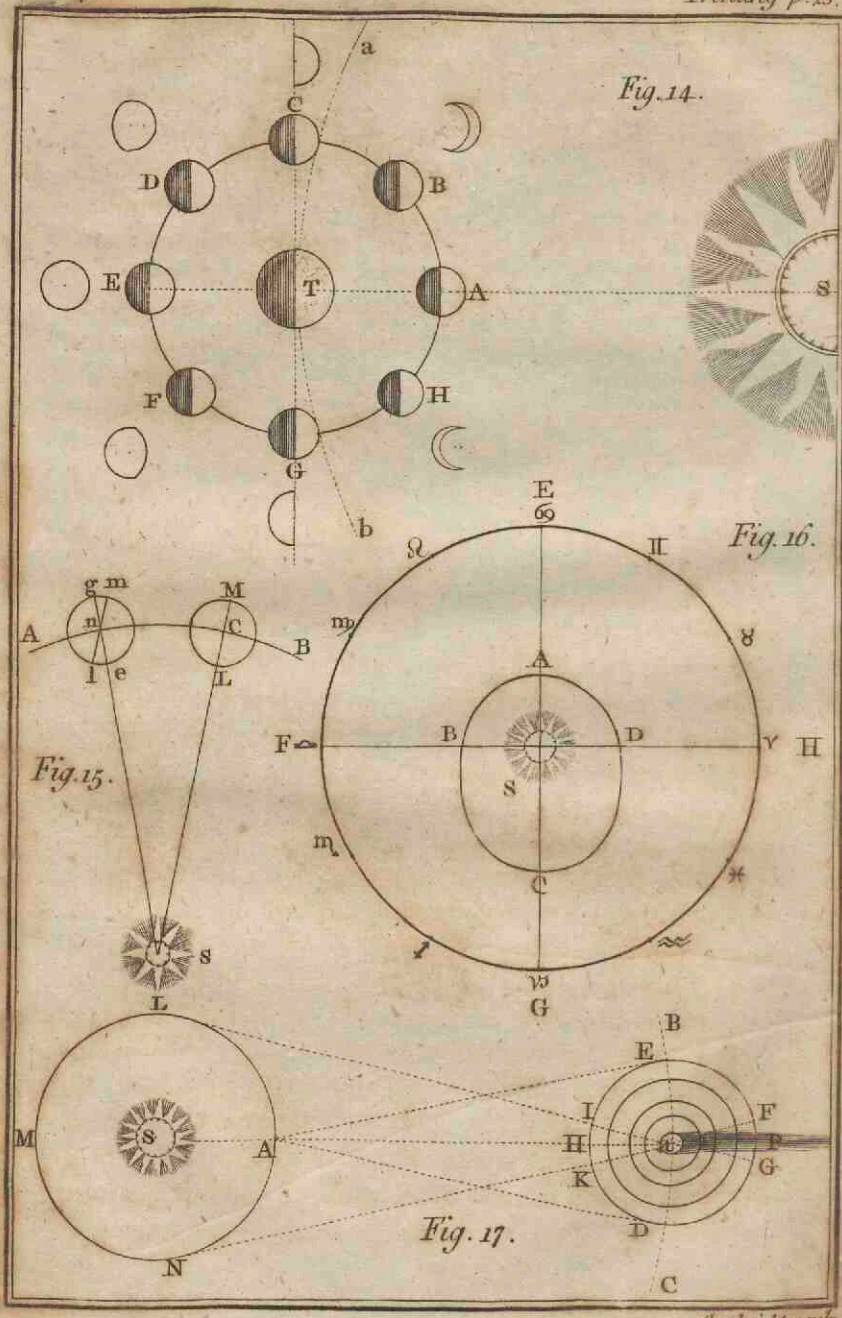
eccentricity and inclination are both variable. The orbit which the moon describes round the earth is elliptical, the earth being in one of its foci; and when the moon is at her greatest distance from the earth, or in her higher apsis, she is said to be *in apogæo*; and when in her lower apsis, or least distance, *in perigæo*.

57. When the moon is at A, fig. 14, in conjunction with the sun at S, and the earth at T, it is called New Moon; and when in opposition at E, it is called Full Moon. The syzigies of the moon is a common term to express both its conjunction and opposition.

58. The moon's ascending node is called the Dragon's Head, and is thus marked ☊; its descending node the Dragon's Tail ☋.

59. A periodical month contains 27 d. 7 h. 43 m. in which time the moon describes her orbit; a synodical month contains 29 d. 12 h. 43 m. 3 s. which is the time that passes between one new or full moon, and the next of the same name which succeeds it; this is longer than a periodical month about 2 d. 5 h.

60. In fig. 15, S represents the sun, A B part of the earth's orbit, M L represents a diameter of the moon's orbit, when the earth is at C; and m l another diameter, parallel to M L of the same orbit, when the earth is removed to D. Whilst the earth is at C, and the moon at L, in conjunction with the sun, as the earth moves from C to D, and the moon's orbit moves with it, the diameter M L will then be in the position m l; so that when the moon has described its orbit it will be at l; but when the sun being at S, the moon will not yet be in conjunction; therefore the periodical month is completed before the synodical, and before the moon can come into conjunction with the sun. When the earth is at D



Goodnight sculp

she must move from l to e, in the diameter g e; whence, besides going round her orbit, she must describe the arc l e, consequently the synodical is longer than the periodical month by the quantity of the arc l e.

61. We do not see the moon at the conjunction, but at the opposition her whole disc is enlightened.

In fig. 14, a T b represents a part of the earth's orbit, S the sun, T the earth, A C E G the moon's orbit. If the moon is at A, it will be on the same side of the earth with the the sun, or in conjunction; and the sun will then be beyond the moon: therefore the sun does not shine on that hemisphere of the moon towards us; whence to us her whole disc must be dark.

62. When the moon is at E, it will be in opposition, and the earth between it and the sun; consequently that hemisphere which is visible to us, wil be the same hemisphere upon which the sun shines, therefore her whole disc towards us will be enlightened, or the moon will be full.

63. Fig. 14. The moon's disc is half enlightened when she is near the quadratures at C or G, her apparent distance from the sun at S being then 90 deg.: when the moon is between the conjunction at A, and either of the quadratures G or C, the illuminated part of it appears horned, as at H and B. When between the full at E, and the quadratures G or C, the disc appears gibbous, as at D and F. When the moon is at A, it is new; as she moves from A to C, it is said to be in the first quarter; from C to E, in the second quarter; from thence to G, in the third quarter; and from G to A again, in the last quarter.

After the new moon, her horns are turned towards the east, and before new moon towards the west; and when she is horned, that part of her disc upon which the sun does not shine, has yet light enough to make it faintly visible.*

The same side of the moon is always turned towards the earth, and her surface is not smooth, but uneven and mountainous, as may be seen with the assistance of a telescope, either in the first or last quarter.

THE SATELLITES OF JUPITER AND SATURN.

64. The distance of Jupiter's innermost satellite from his center is 5.667 semidiameters of the planet; the second, 9.017; the third, 14.381; and the fourth, 25.299 semidiameters.

The periodical time of Jupiter's first satellite is 1 d. 18 h. 27 m. 34 sec. The second is 3 d. 13 h. 13 m. 42 sec. The third is 7 d. 3 h. 42 m. 36 sec. And the fourth is 16 d. 16 h. 32 m. 9 sec.

65. The plane of the orbit of every secondary planet is parallel to itself in every part of the orbit of its primary. The orbits of all Jupiter's satellites are nearly, but not exactly, in the same plane; which produced makes an angle with the orbit of Jupiter of about 3°; the second deviates a little from the rest.

66. A satellite in one of its nodes appears in the orbit of its primary: in all other parts of its orbit it has latitude.

* This faint light, by which we sometimes can distinguish the remaining portion of the moon's disk, is occasioned by the reflected light of the earth; and as the land reflects more light than the water, it has been observed that this appearance is more visible when the continental parts of the earth are opposite the moon, than when the great ocean is in the same situation.

If the plane of any circle produced passes through the eye, it appears to be a straight line; consequently every circle, viewed obliquely, will appear elliptical; so that

When a satellite is in its node, at the same time that its primary's heliocentric place is in the same degree of the ecliptic with it, and the earth in its geocentric node; at that time the orbit of the satellite appears a straight line. When the primary is in any other part of his orbit, the satellite's orbit will appear an ellipsis, whose shortest axis increases in proportion as the primary is farther distant from the satellite's node.

The orbit of the earth is so small, when compared to those of Jupiter and Saturn, that in whatever part of her orbit she may happen to be, when either of these planets are in the nodes of their satellites, these last will appear to describe lines very nearly straight

67. When a satellite is in that semicircle which is farthest from the earth, its geocentric motion is direct; when it is in that nearest to the earth, its geocentric motion is retrograde.

Any satellite is at its greatest elongation from its primary, when a line, supposed to be drawn from the earth through the satellite, is a tangent to the satellite's orbit.

In fig. 17. B a C represents a part of Jupiter's orbit, N A L M, the earth's orbit, S the sun, D G F H the orbit of Jupiter's outermost satellite. When the earth is at A, and the satellite at E or D, in the tangent line A E or A D, then this satellite, seen from the earth at A, will appear at a greater distance from the primary, than it can do in any other situation.

68. Every satellite appears in conjunction with its primary, when it is between the earth and its primary; and also, when the primary is between the earth and satellite; the first is called its inferior, the last its superior conjunction.

The apparent motion of any satellite is direct, as it passes from D, fig. 17, its greatest elongation, through P, its superior conjunction, to E, its greatest elongation on the other side; its geocentric motion seen from the earth at A, being then from west to east, *in consequentia*, or according to the order of the signs.

Any satellite's apparent motion is retrograde, as it passes from E, its greatest elongation on one side of its primary, through H, the inferior conjunction, to D, its greatest elongation on the other side; it is therefore plain, that its motion seen from the earth at A, is from east to west, *in antecedentia*, or contrary to the order of the signs.

69. The satellites are seen sometimes to the west, and sometimes to the east of their respective primaries: they cannot be seen in their superior conjunction, and are seldom distinguished from their primary in their inferior conjunction.

70. The distance of Saturn's innermost satellite from the center of the primary, is 1,93 semidiameters of the ring, the second 2,47, the third 3,47, the fourth 8,00, and the distance of the fifth 23,45 semidiameters of the ring.

The periodical time of Saturn's innermost satellite is 1 d. 21 h. 18 m. 27 sec. The second, 2 d. 17 h. 41 m. 22 sec. The third, 4 d. 12 h. 25 m. 12 sec.

The fourth, 15 d. 22 h. 41 m. 14 sec. And the fifth satellite's periodical time is 79 d. 7 h. 48 m.*

71. The satellites of Jupiter and Saturn cast a shadow upon their primary, which may be seen to pass over the disc of the planet like a spot; they also frequently fall into the shadow of their primaries, and are eclipsed; which may be observed by the help of a telescope.

72. Fig. 12, 13, represent the different magnitudes of the primary and secondary planets, with the proportion which they bear to each other, and to a globe of twelve inches diameter, which is supposed to represent the sun.†

* Two more satellites have since been discovered by Herschel: their periodic times are . .

d.	h.	m.
0	22	37
1	8	53

The mean distances of the seven satellites, expressed in semidiameters of the planet, are . .

I.—	3.08
II.—	3.95
III.—	4.89
IV.—	6.26
V.—	8.75
VI.—	20.29
VII.—	59.19

† Uranus has six satellites: their mean distances, in semidiameters of the planet, are as follow:

I.—	13.12
II.—	17.02
III.—	19.84
IV.—	22.75
V.—	45.50
VI.—	91.01

Sidereal revolutions:

	d.	h.	m.
I.—	5	21	25
II.—	8	16	58
III.—	10	23	3
IV.—	13	10	56
V.—	38	1	48
VI.—	107	16	40

It is a very remarkable circumstance, that the planes of the orbits of these planets are nearly perpendicular to the ecliptic.

THE PARALLAX OF THE HEAVENLY BODIES

73. Is the change of their apparent places, when viewed from different stations.

The diurnal parallax is the change of the apparent place of a fixed star or planet, or of any celestial body, arising from its being viewed on the surface, or from the centre of the earth. The fixed stars have no diurnal parallax, the moon a considerable one: that of the planets is greater or less, according to their distances.

74. In fig. 18, I A K represents the earth, T its center, A B the sensible, T L the real horizon of a spectator upon the earth at A, M the moon, S the sun, both in the sensible horizon: if seen from A, they will appear in the horizon at B; but if seen from T, the center of the earth, they would appear amongst the fixed stars at C and D; that is, the moon would appear in the line T M D, and the sun in the line T S C: these are called their true places; the arch B C is called the sun's parallax, and B D that of the moon. The angles B S C, and B M D, are called the parallactic angles, which are respectively equal to the angles A S T, and A M T; under which, A T, a semidiameter of the earth passing through A, the place of the spectator, would appear, if seen from the sun or moon.

75. If a planet is above the horizon at E, its true place seen from T, the center of the earth is at F, its apparent place at G, and its parallax is F G. Hence it is plain, that the higher the planet is elevated above the horizon, the less is its parallax; and when it is directly over the head of the spectator at H, it will have no parallax at all; its apparent place in the

Fig. 18.

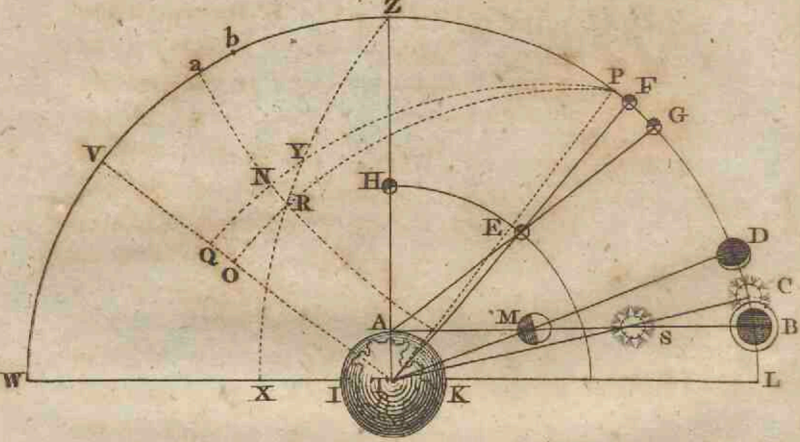
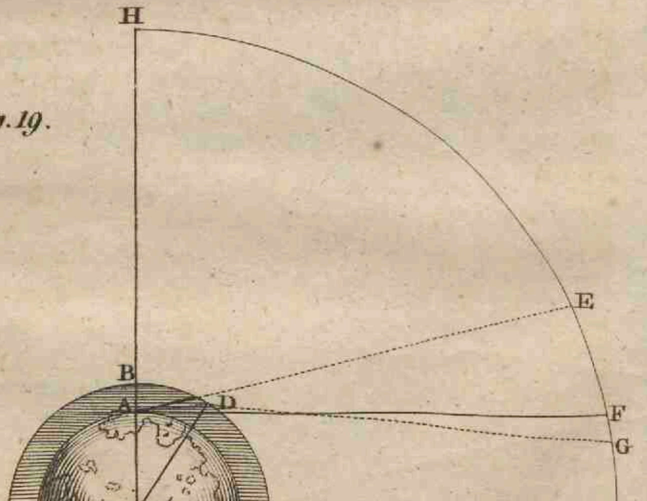


Fig. 19.



Goodnight sculp

heavens being Z, whether it be seen from A or T.* It is observable, that the apparent place G, of a planet at E, seen from the earth at A, is always lower or farther from the zenith Z, than F, its true place seen from T, except when the planet is vertical, or at H; so that the horizontal parallax is greatest of all.

76. The diurnal parallax of a planet in a vertical circle causes one of right ascension and declination, unless it be on the meridian, when there is only a parallax of declination: it also causes a parallax of longitude and latitude, unless the vertical circle is a secondary of the ecliptic.

In fig. 18. W L represents the horizon, V T an arch of the equator, cutting the horizon at T; T P the axis of the world, and P the celestial pole, Z the zenith, Z X a vertical circle, R the planet's apparent place therein, if seen from the earth's surface; and Y its apparent place in the same vertical, if it could be seen from the earth's center: then R Y is its parallax. P R O is a secondary of the equator, passing through the planet, and P Y Q, another secondary, passing through its apparent place at Y; whence its declination, seen from the center, is O R, and from the surface Q Y; the difference N Y, between Q Y and Q N, is the parallax of declination. When the planet is at R, the secondary P R O passes through the point O of its right ascension upon the equator,

* This is upon the supposition that the earth is spherical. From the elliptical form of the terrestrial meridian, the direction of a plumb line, or vertical, does not exactly pass through the center of the earth; hence it arises, that the moon, when in the zenith, has nevertheless a small parallax, which must be attended to in exact observations.

but the secondary P Y Q passes through Y, the planet's apparent place, and Q its right ascension upon the equator; whence the parallax R Y makes a difference, or parallax, Q O, in right ascension.

77. If a be the apparent place of a planet upon the meridian Z V W, when seen from the surface, and b when viewed from the center of the earth, a b is its diurnal parallax in a vertical circle Z W to the horizon; but this same circle is also a secondary to the equator, whence there can be no parallax of right ascension.

Now suppose P the pole of V T, which is now called an arch of the ecliptic, cutting the horizon W L in T, Z X a vertical circle, let R Y be the planet's parallax, P R O a secondary of the ecliptic passing through the planet, when seen at R from the surface of the earth; P Y Q another secondary, passing through it, if it could be viewed from the earth's center, so as to appear at Y; when at R, its latitude is R O, when at Y, its latitude is Q Y, the difference N Y is the parallax of latitude.

78. When the planet appears at R in P R O, the secondary of the ecliptic, the point O is its longitude from the first point of Aries; but when at Y in the secondary P Y Q, Q is the point of its longitude; whence the difference Q O is the parallax of longitude.

But if the planet be in a vertical circle Z W, which passes through P, the pole of the ecliptic, it can only have a parallax of latitude, and none of longitude. Let a b be the parallax of latitude; whence from either station, a b will be its parallax of latitude; and as there can pass but one secondary through both, there can be no parallax of longitude.

The annual parallax of any heavenly body arises from its being seen from the earth when it is in different parts of its orbit.

THE REFRACTION OF THE ATMOSPHERE.

79. If a ray of light enters a transparent medium obliquely, it does not pass straight on, but is bent at the point at which it enters: this bending is called refraction.

In fig. 19. A C represents the surface of the earth, T its center, B P a part of the atmosphere, H E K the sphere of the fixed stars, A F the sensible horizon, G a planet, G D a ray of light proceeding from G to D, where it enters our atmosphere, and is refracted towards the line D T, which is perpendicular to the surface of the atmosphere: and as the upper air is rarer than that near the earth, the ray is continually entering a denser medium, and is every moment bent towards T, which causes it to describe a curve, as D A, and to enter a spectator's eye at A as if it came from E, a point above G. And as an object always appears in that line in which it enters the eye, the planet will appear at E, higher than its true place, and frequently above the horizon A F, when its true place is below it at G.

The greatest refraction is when the planet, &c. is seen in the horizon, being 33 min. When its altitude is 20 deg. the refraction is 2 min. 14 sec.: at 40 deg. of altitude it is 58 sec.: at 60 deg. of altitude it is 29 sec. and so becomes insensible, as the altitude increases.

SOLAR AND LUNAR ECLIPSES.

80. An eclipse is a deficiency of light in the heavenly bodies In an eclipse of the sun, its light

is intercepted from the sight of the inhabitants of any part of the earth, by the moon passing between them and the sun; and as its disc is either partly, or wholly covered, it is called a partial or total eclipse.

An eclipse of the moon is caused by her passing through the shadow of the earth, whereby she is deprived of the sun's light.

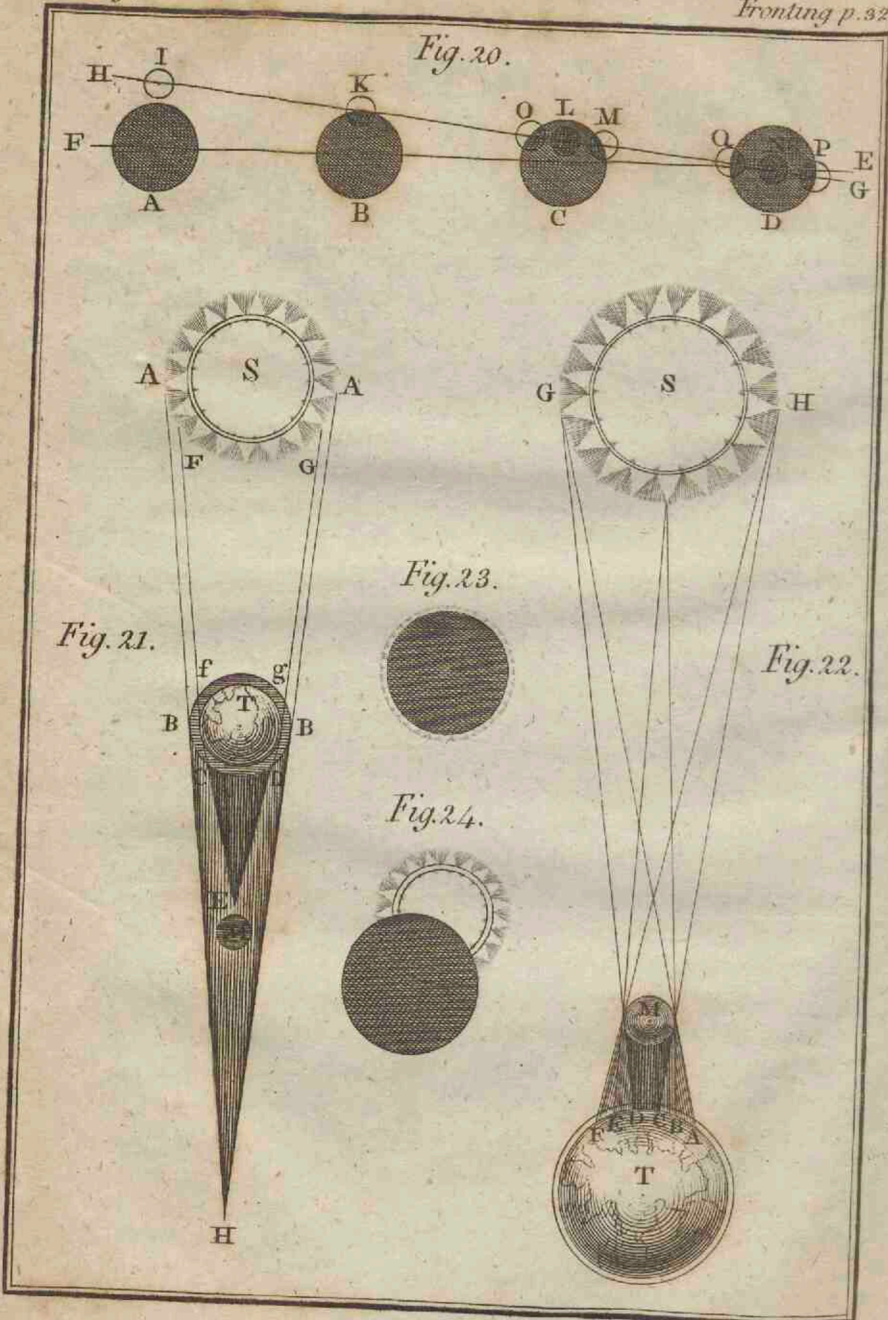
The sun can never be eclipsed but at the time of New Moon; neither can there be an eclipse of the moon, but at the time of the full moon: In the first case, the new moon must be within 18 degrees, in the last, the full moon within 12 degrees, of one of her nodes.

These luminaries are not eclipsed every new and full moon, because the moon's motion is not in the plane of the ecliptic, in which the sun and earth always are.

Hence the moon's latitude is oftentimes so much increased at the time of the new moon, that her shadow does not touch the earth; and at the time of full moon, she as frequently passes by the earth's shadow without entering into it: but when the moon's latitude is inconsiderable, which only happens when she is within the limits above mentioned, she then appears either in or near the ecliptic.

Let H G, fig. 20, represent the path of the moon E F, the plane of the ecliptic, in which the center of the earth's shadow always moves; N, the node of the moon's orbit; A, B, C, D, represents four places of the earth's shadow in the ecliptic: when her shadow is at A, and the moon passing by at I, she will not enter into the shadow; but when the full moon is nearer to the node at K, only part of

Fronting p. 32.



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29

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1810
hier: verklaring van zon- en maansverduistering

her globe passes through the shadow B, and that part becomes dark: this is called a partial eclipse. When the full moon is at M, she enters into the shadow C; in passing through it, she becomes wholly darkened at L, and leaves the shadow at O. This is called a total eclipse: and when the moon's center passes through that of the shadow, which can only happen at the very time she is in the node at N, it is called a central eclipse.

We have not yet mentioned the atmosphere, which requires our consideration, while we are treating of lunar eclipses; for the shadow of the earth does not reach the moon. In fig. 21, T represents the earth, B C D B g f its atmosphere, A B, A B, rays proceeding from the sun at S, touching the atmosphere at B and B; these go straight on, and terminate the shadow of the atmosphere at H. The moon is constantly enlightened by the sun's rays until she enters this shadow, when she becomes fainter, as she continues to move between A B H and ABH.

The rays which enter the atmosphere obliquely, are refracted, and bent into curves that touch the earth; all the light between F f and G g, is intercepted by the earth; and the rays C E, D E, terminate the earth's shadow.

The light between F f, and A B, is refracted by the atmosphere, and diffused between C E, and A B, and continued beyond E, the point of the earth's shadow: whence it is plain, that the light proceeding from the sun becomes continually weaker, the farther it is from the earth; so that the shadow of the atmosphere is but a weak light, and therefore the moon is visible in an eclipse.

The shadow of the atmosphere is conical, because the diameter of the sun is greater than that of the earth. This cone does not reach so far as the planet Mars: but the diameter of the shadow, in the place where it cuts the moon's orbit, is not $\frac{1}{4}$th less than the earth's diameter.

A solar eclipse happens, when the new moon is in or near the node. In fig. 22, S represents the sun, M the moon, her shadow falling upon D C, a part of the earth's circumference, which is surrounded by a penumbra. Beyond A and F, the earth is illuminated by an entire hemisphere of the sun. As you move from A to C, or from F to D, the light is continually diminishing; and near C and D, the rays come to the earth only from a small point of the sun's surface.

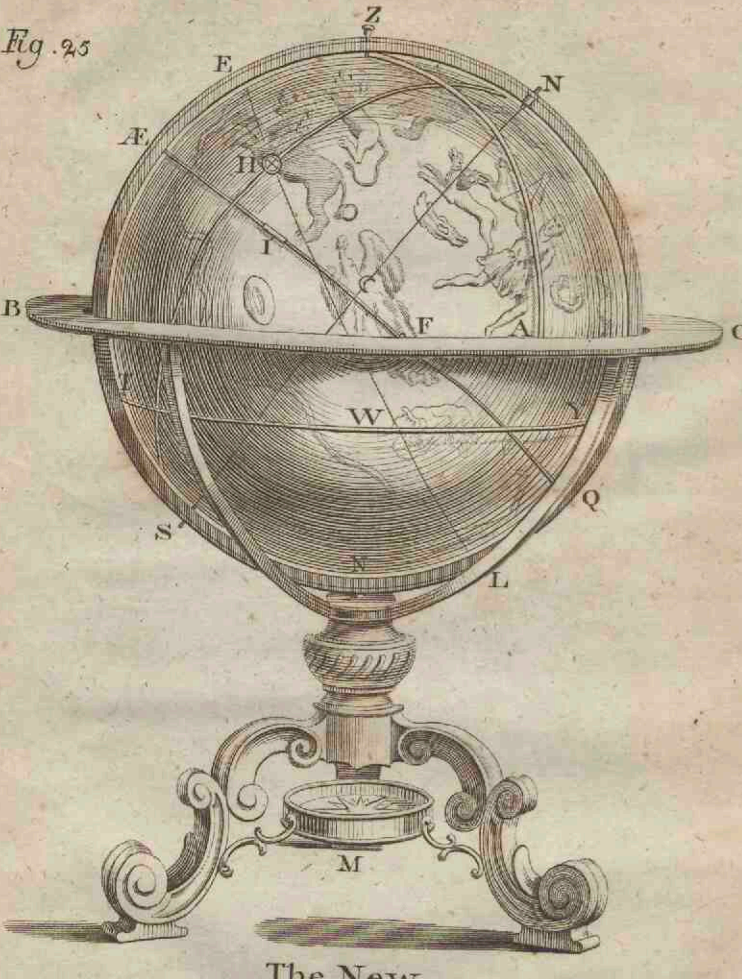
This diminished light, which surrounds the shadow every way, is called the penumbra. An observer at B or E can only see half the sun's diameter, the rest being hidden by the interposition of the moon. If the observer moves from B to C, or from E to D, the sun will be more and more withdrawn from his sight, until it becomes wholly invisible in the shadow itself; whence it is plain that there may be a solar eclipse, although the shadow of the moon does not touch the earth, if the penumbra comes to its surface.

When the moon's shadow falls upon the earth, it is called a total eclipse of the sun; if the penumbra only reaches the earth, it is called a partial eclipse of the sun: with respect to particular places, it is said to be total where the shadow passes; central, where the center of the moon covers that of the sun; and partial, where the penumbra only goes by, as is represented in fig. 23.

The wider the shadow C D, fig. 22, is, the longer the sun will be totally eclipsed, and a larger space of the earth will be under the shadow; but its breadth will vary, as the distance of the moon from the earth, and of the earth from the sun, varies; for when the earth is *in perihelion*, and the moon *in apogee*, that is, at its greatest distance from the earth, the shadow of the moon does not reach the earth, and the moon does not cover the sun; this is called an annular eclipse, as is represented in fig. 24.

[illegible] when the shadow C D, [illegible], is the longer the moon will be [illegible] reduced [illegible] appear [illegible] the sun [illegible] its breadth when we see the [illegible] of the moon [illegible] the earth [illegible] [illegible]; and when the earth is in perihelion, and the moon in apogee (that is,) at its greatest distance from the earth, the shadow of the moon does not reach the earth, and the moon does not cover the sun; this is called an annular eclipse, as is represented in fig. [illegible]

Fig. 25



The New

CELESTIAL GLOBE,

As Improved and Constructed by D. ADAMS

Fleet Street LONDON.

THE

DESCRIPTION AND USE

OF THE

NEW CELESTIAL AND TERRESTRIAL

GLOBES.

IF the periphery of a semi-circle be turned round its diameter as an axis, it will generate the surface of a globe or sphere, and the center of the semi-circle will be the center of the globe: it therefore follows, that as all the points in the circumference of the semi-circle are at an equal distance from its center, so all the points of a globe, thus generated, must be the same.

82. Any straight line passing through the center of a globe, being terminated by its surface, is called a diameter; and that diameter about which the globe turns, is called its axis; the extremities of which are called the poles of the globe.

83. There are two artificial globes. That on which the surface of the earth is represented, is called the terrestrial globe.

84. The other on which the face of the starry sphere is delineated, is called the celestial globe.

85. In the use of the terrestrial globe, we are to consider ourselves standing upon some part of its

surface, and that its motion represents the real diurnal motion of the earth, which is from west to east.

86. In the use of the celestial globe, we are to suppose ourselves at the center, and that its motion represents the apparent diurnal motion of the heavens, which is from east to west.

87. Note, The stars being delineated upon the convex surface of the celestial globe, we must suppose ourselves at the center; because under such a supposition they would appear, as they naturally do, in the concave surface of the heavens.

88. Several circles are described upon the surface of each globe. Those whose planes pass through the center of the globe, are called great circles; some of which are graduated into 360 degrees, 90 of which make a quadrant.

89. Those circles whose planes do not pass through the center of the globe, are called lesser circles.

90. Our new terrestrial and celestial globes, fig. 1, and fig. 25, are each of them suspended at their poles in a strong brass circle N Z Æ S N, and turn therein upon two iron pins, which are the axis of the globe. They have each a thin brass semi-circle N H S moveable about the poles, with a small thin sliding circle thereon.

91. On the terrestrial globe, fig. 1, this semicircle N H S is a moveable meridian, and its small sliding circle H, the visible horizon of any particular place to which it is set. But,

92. On the celestial globe, fig. 25, this semicircle N H S is a moveable circle of declination, and its small circle H, an artificial sun or planet.

93. Each globe hath a brass wire circle, T W Y, placed at the limits of the crepusculum, or twilight, which, together with the globe, is set in a wooden frame: the upper part B C is covered with a broad paper circle, whose plane divides the globe into two hemispheres, and the whole is supported by a neat pillar and claw, with a magnetic needle in a compass box at M.

94. On our new terrestrial globe, the division of the face of the earth into land and water is accurately laid down from the latest and best astronomical, geographical, and nautical discoveries. There are also many additional circles, as well as the rhomb-lines, for the greater ease and convenience in solving all the necessary geographical and nautical problems.

95. On the surface of our new celestial globe, all the southern constellations, lately observed at the Cape of Good-Hope by M. de la Caille, and all the stars in Mr. Flamsted's British Catalogue, are accurately laid down, and marked with Greek and Roman letters of reference, in imitation of Bayer. Upon each side of the ecliptic are drawn eight parallel circles at the distance of one degree from each other, including a space of sixteen degrees, called the zodiac; these are crossed at right angles with segments of great circles at every fifth degree of the ecliptic, for the readier noting the place of the moon or any planet upon the globe.

96. We have also inserted from Ulugh Beigh, printed at Oxford, A. D. 1665, the manazil al kamer, i. e. the mansions of the moon of the Arabian astronomers; which are so called, because they observed the moon to be in or near one of these every night,

during her monthly course round the earth, to each of which the Arabian characters are affixed. They may be of very great use to beginners to teach them the names of the stars, as well as to mariners for the same purpose; who may have occasion to observe the distance of the moon from a fixed star, in the new method of discovering the longitude at sea. They will likewise serve to shew, how the moon passes from star to star in the course of one or several nights, which is a very curious and useful amusement; and as they are a division of the heavens different from any thing the Greeks were acquainted with, and therefore not borrowed from them, and as we do not know they were ever inserted to any globe before, we hope we have with propriety placed them on our new celestial globe. *See* Costard's *Hist. of Astronomy, p.* 40.

THE BROAD PAPER CIRCLE B C ON THE SURFACE OF THE WOODEN FRAME WHICH SUPPORTS THE BRASS MERIDIAN

97. Contains four concentric circular spaces. The innermost of which is divided into 360 degrees, and numbered into four quadrants, beginning at the east and west points, and proceeding each way to 90 degrees at the north and south points; these are the four cardinal points of the horizon. The second circular space contains, at equal distances, the thirty-two points of the mariner's compass. Another circular space is divided into twelve equal parts, representing the twelve signs of the zodiac; these are again subdivided into 30 degrees each, between which are engraved their names and characters. This space

is connected with a fourth, which contains the kalendar of months and days; each day, on the new eighteen-inch globes, being divided into four parts, expressing the four cardinal points of the day, according to the Julian reckoning; by which means the sun's place is very nearly obtained for the three common years after bissextile, and the intercalary day inserted without confusion. Whence we derive the following

PROBLEM I. *To find the sun's place any day in the year on the broad paper circle.*

98. Consider whether the year in which you seek the sun's place is bessextile, or the first, second, or third year after.

99. If it be the first year after bissextile, those divisions, to which the numbers for the days of the month are affixed, are the respective days for each month of that year at noon; opposite to which, in the circle of twelve signs, is the sun's place.

100. If it be the second year after bissextile, the first quarter of a day backwards, or towards the left hand, is the day of the month for that year; against which, as before, is the sun's place.

101. If it be the third year after bissextile, half a day backwards is the day of the month for that year, opposite to which is the sun's place.

102. If the year in which you seek the sun's place is bissextile, then three quarters of a day backwards is the day of the month from the 1st of January to the 28th day of February inclusive. The intercalary, or 29th day, is three fourths of a day to the left hand from the 1st of March; and on the 1st of March itself is one quarter of a day forward, from the

division marked 1; and so for every day in the remaining part of the leap-year; against each of which is found the sun's place.

In this manner the intercalary day is very well introduced every fourth year into the kalendar, and the sun's place very nearly obtained according to the Julian reckoning. Thus:

A. D.		Sun's place, April 25.
1769.	first year after bissextile - -	♉ : 5° : 21′
1770.	second - - - - - - - - - - -	♉ : 5° : 06′
1771.	third - - - - - - - - - - - -	♉ : 4° : 55′
1772.	bissextile - - - - - - - - - -	♉ : 5° : 35′

One use of the broad paper circle is to distinguish the points of the horizon; in this case it represents the rational horizon of any particular place, which is an imaginary great circle in the sphere of the heavens, dividing the visible from the invisible hemisphere. This is supposed to be parallel to a lesser circle, called the sensible horizon, whose plane may be conceived to touch the surface of the globe at that place upon which an observer stands, and to terminate his sight when he views the heavens round about. The extent of the sensible or visible horizon is greater or less, as we stand higher or lower.

103. Another use we shall make of this circle is to represent the circle of illumination, or that circle which separates day from night.

A third use to which this circle may be applied, is to represent the plane of the ecliptic. All of which shall be illustrated in their proper places.

In all positions of the celestial globe, this broad paper surface is the plane of the horizon, and distinguishes the visible from the invisible part of the heavens.

Note, As this circle occasionally represents various great circles of the sphere, we have given it the name of broad paper circle, to prevent the reader from considering it as an horizon, when it really represents the plane of the earth's illuminated disc, &c.

The north-side of the wooden frame ought to be placed directly towards the north-side of the heavens, which is readily done by the mariner's compass under our new globes.

THE STRONG BRASS CIRCLE, OR MERIDIAN, N Z Æ S N.

104. There are two notches in the broad wooden circle (Art. 97) upon the plane of which the broad paper circle is placed, which receive the strong brass circle: the body of the globe, being suspended at two opposite points in this circle, turns round therein on its iron poles, one of which N represents the north, and the other S the south pole.

105. One side of this strong brass circle is graduated into four quadrants, each containing 90 degrees. The numbers on two of these quadrants increase from the equator towards the poles; the numbers on the other two increase from the poles towards the equator.

" The reason why two quadrants of the meridian
" are numbered from the equator, and the other
" two from the poles, is because the first of these
" two shew the distance of any point on the globe
" from the equator or equinoctial, and the other
" serves to elevate the globe to the latitude of any
" place."

106. The strong brass circle of the celestial globe is called the meridian, because the sun's center is directly opposite thereto at noon.

107. On the strong-brass circle of our new terrestrial globe, and about 23½ degrees on each side of the north pole, the days of each month are laid down according to the sun's declination. If any day of the month is placed in the plane of the horizon, it will shew the sun's declination for that day upon the other side of the brass meridian; and this brass circle is so contrived, that the globe may be placed in the position of a direct or right sphere, (which is, when the north and south poles are placed in the plane of the broad paper circle) and also that the south pole may be elevated above the plane of the broad paper surface, with as much ease as the north pole. A circumstance which we thought not unworthy of our attention in the construction of our new globes.

108. The graduated side of the strong brass circle, encompassing our new terrestrial globe, faces the west; being most agreeable to the real diurnal motion of the earth, which is from west to east.

109. But that which surrounds the celestial globe, faces the east, as the apparent diurnal motion of the heavens is from east to west.

110. In all inclinations of either globe, the north pole should be directed towards the north point of the heavens, which the mariner's compass at M, placed under each of the globes, will enable us to do with the greatest readiness.

THE HORARY CIRCLE.

111. We use no other circle to measure the hours

and minutes of time, but the equator, upon the surface of either globe; it being not only the most natural, but the largest circle that can possibly be applied for that purpose. This is done by a semicircular wire Æ F placed in the plane of the equator, carrying two indices; one of which, I, is occasionally to be used to point out the time.

As the first meridian in our new globes passes through London, it therefore becomes the XII o'clock hour circle; and this falls upon the intersection of the equator and ecliptic at the first point of Aries; the other XIIth hour circle passes through the opposite intersection at the first point of Libra.

Remember, when the globe shall be hereafter rectified for London, or any other place, on the same meridian with it, that then the graduated side of the strong brass meridian is the horary index itself.

It may happen, that the globe shall be so rectified as that the two points of XII o'clock will fall in, or so near, the east and west points of the broad paper circle, that neither of the horary indices can be applied thereto, in such a case either of these points themselves will be the horary index.

112. The hours and minutes are graduated below the degrees of the equator on either globe; and as

113. The motion of the terrestrial globe is from west to east, the horary numbers increase according to the direction of that motion.

114. The motion of the celestial globe being from east to west, the horary numbers increase in that direction.

THE THIN BRASS SEMI-CIRCLE N H S.

115. This turns upon the poles of the globe, and

may be called a proper or a moveable meridian. It is graduated each way to 90 degrees from the equator to either pole.

116. To this semi-circle on the new celestial globe, fig. 25, is fitted a small thin brass circle H, about half an inch diameter, which slides from pole to pole; when we consider the sun's apparent diurnal motion, we call it an artificial sun.

117. But to the thin semi-circle applied to the new terrestrial globe, fig. 1, is fitted a small thin circle H, about two inches diameter, that slides from pole to pole; which is divided into a few of the points of the mariner's compass, and is called a terrestrial or visible horizon.

THE BRASS QUADRANT OF ALTITUDE Z A,

118. Is a thin narrow flexible slip of brass, that will bend to the surface of the globe; it has a nut with a fiducial line upon it, which may be readily applied to the divisions on the strong brass meridian of either globe; one of its edges is graduated into 90 degrees, and continued to 20 degrees below the horizon. Upon the terrestrial globe, its use is to shew the distance of places; and when applied to the celestial globe, it shews the distance between two stars. If affixed to the zenith or pole of the horizon, it shews the altitude of any point upon the globe, its graduations being numbered upwards from the horizon to 90 degrees, and downwards to 20 degrees for the depression of any celestial object. It will represent any vertical circle passing through the pole of the horizon, in its motion round the zenith point, as well as the prime vertical, which passes through

through the east and west points of the horizon. Upon both globes it occasionally shews the distance of every secondary to the horizon; and has other uses, which will be hereafter shewn.

119. *Note, When we speak of bringing any point, or place to the strong brass meridian, we mean that it should be brought to its graduated side, which is properly the meridian.*

Also, when we speak of bringing the moveable meridian, quadrant of altitude, or any other thin flexible circle, to any point or place; we mean that their graduated edges should be brought to that point, or place.

OF THE SEVERAL CIRCLES DESCRIBED UPON THE SURFACE OF EACH GLOBE.

120. We may imagine as many as we please upon the surface of the earth, and conceive them to be extended to the sphere of the heavens, marking thereon concentric circles.

121. The planes of all great circles pass through the center, and divide the globe into two equal hemispheres: a small circle divides the surface of a globe into two unequal parts; all circles are supposed to be divided into 360 degrees.

We shall begin with the description of the equator, this being the most eminent great circle on either globe.

THE EQUATOR OR EQUINOCTIAL Æ I Q,

122. Is 90 degrees distant from the two poles of the globe; and is so called, because when the sun appears to pass vertically over this circle, the days

and nights are of an equal length to all the inhabitants of the earth.

123. This plane of the equator passes through the middle of the globe at right angles to the polar axis.

On our new globes it is graduated into 360 degrees; upon the terrestrial globe, the numbers increase from the meridian of London westward, and proceed quite round to 360.

124. They are also numbered from the same meridian eastward by an upper row of figures, for the ease of those who use the English tables of the latitude and longitude of places.

125. On our new celestial globes the equatorial degrees are numbered from the first point of Aries eastward, to 360 degrees.

126. Close under the degrees, on either globe, is graduated a circle of hours and minutes.

127. On the celestial globe, the hours increase eastward from Aries to XII at Libra, where they begin again in the same direction, and proceed to XII at Aries.

128. But the horary numbers under the equator of the terrestrial globe, increase by twice twelve hours westward, from the meridian of London, to the same again.

129. In every position of the globe, except that of a parallel sphere, the plane of the equator cuts the eastern and western points of the broad paper circle, when considered either as an horizon, the ecliptic, or circle of illumination.

And as the globe is turned about, it always keeps to one point of the strong brass circle, in which, as hath been observed, the degrees are numbered both ways from the equator, that the distance of latitude north or south of any point on the surface of the globe may be more easily computed. Whence arises the following

PROBLEM II. *To find the latitude of a place.*

130. Bring the place to the graduated side of the strong brass meridian; the degree it then cuts shews its distances from the equator, which on the terrestrial globe is called latitude.

Thus London has 31 deg. 32 min. of north latitude; Constantinople, 41 deg. of north latitude; Quebec, in Canada, 46 deg. 55 min. of north latitude; and the Cape of Good Hope, 34 deg. south latitude.

PROBLEM III. *To find all those places which have the same latitude with any given place.*

131. Suppose the given place London; turn the globe round, and all those places which pass under the same point of the strong brass meridian are in the same latitude.

PROBLEM IV. *To find the difference of latitude between any two places.*

132. Suppose London and Rome, find the latitude of each place by Prob. ii. Art. 130. Their difference is the answer.

PROBLEM V. *To find the declination of the sun.*

133. First, On either globe for the sun's declina-

tion, find his place in the ecliptic by Prob. i. Art. 98, &c. Then bring that point of the ecliptic line upon the globe under the strong brass meridian, and the degree which it cuts is the sun's declination for that day. Or,

Upon the terrestrial globe, that parallel which passes through the point of the ecliptic answering to the day of the month, will shew the sun's declition, counting the number of parallels from the equator, Also,

On the celestial globe, seek the day of the month close under the ecliptic line itself, against which is the sun's place; bring that point under the strong brass meridian, and the degree that stands over it is the sun's declination for that day. Thus on the 23d of May the sun's declination will be about 20 deg. 10 min. and upon the 23d of August it will be 11 deg. 13 min.

FOR THE DECLINATION OF ANY STAR.

134. Secondly, Bring the star to the strong brass meridian on the celestial globe, and the degree it stands under is its distance from the equator, and this distance is called the star's declination, which may be either north or south, according to the side of the equator on which the star is situated.

Thus the declination of the star Arcturus, marked α in the constellation Bootes, has about 20 deg. 30 min. north declination; and that of Syrius in Canis Major, or the Dog star, marked α, has about 16 deg. 30 min. south declination.

135. Hence we see, that the latitude of places on the earth, and the declination of the sun and stars, &c.

in the heavens, have but one idea, the meaning of which is no more than their distance (either of places on the terrestrial, or of the luminaries in the celestial spheres) from the equator.

The latitude of a fixed star always continues the same, but that of the sun, moon, and planets, varies.

136. Those stars, whose declinations are equal to the latitude of any place upon the earth, are called correspondents to that place; and pass once in every 24 hours vertically to the inhabitants of such latitude: that is, those stars appear in their zenith, or are directly over their heads. Hence the following

PROBLEM VI. *To find what stars pass over or nearly over the zenith of any place.*

137. Find the latitude of the place by Prob. ii. Art. 98, upon the terrestrial globe, which is the distance of that place from the equator; then turning the celestial globe, all those stars which pass under the strong brass meridian at the same distance from the equator, will pass directly over the heads of those inhabitants, and therefore become celestial correspondents to all those who live under the same parallel of latitude.

Thus the star marked γ of the second magnitude in the head of the Dragon is 51 deg. 32 min. distant from the celestial equator, so is London at the same distance from the terrestrial equator: therefore the declination of this star is equal to the latitude of London, and consequently it becomes our celestial correspondent.

The star marked α of the second magnitude in Perseus's side, called Algenib, passes over the zenith of those inhabitants in France who live 14 min. of one degree south of Paris; it also passes nearly over the zenith of St. George's Bay in Newfoundland.

CELESTIAL AND TERRESTRIAL MERIDIANS

138 Are great circles drawn upon globes from one pole to the other, and crossing the equator at right angles. Upon our new terrestrial globe there are twenty-four of these meridians, which are also hour-circles, being 15 degrees from each other.

Thus 15 degrees on the equator are equal to one hour, and each single degree equal to four minutes of time. Only four meridians which are also called colures, are drawn upon the surface of the celestial globe.

139. There are no places on the surface of the earth, or spaces in the apparent sphere of the heavens, through which meridians may not be conceived to pass; consequently all points on the terrestrial or celestial spheres have their meridians. So that they only (properly speaking) live under the same meridian, that are under the same semi-circle, on the same side of the poles.

This variety of meridians on the globes is supplied by the thin brass semi-circle, which being moveable about the poles, may be set to every individual point of the equator. Whence we call it a moveable meridian, Art. 115.

140. All those halves of great circles, that are drawn from pole to pole, are the meridians of those places through which they pass, and being perpendicular to the plane of the equator, are called secondaries thereto.

141. One of these meridians on our new terresrial globe passes through London, and is called a first meridian; because from that point which is marked ♈, where it crosses the equator, the degrees of longitude, as well as the hours and minutes of time, begin.

The opposite meridian to this crosses the great Pacific Ocean, and passes through the first point of Libra, marked ♎ upon the globe.

This meridian is graduated from pole to pole, and its numbers increase from the equator each way to the pole. One particular use to which it may be applied, and for which it was at first designed, is to solve some of the cases in spherical trigonometry with ease and propriety, as will be seen hereafter.

Some geographers make their first meridian pass through the isle of Fer, or Ferro.

PROBLEM VII. *To find the longitude of a place.*

142. The longitude of any place is that point or degree upon the equator, which is crossed by the meridian of that place, reckoned from a first meridian.

Bring the moveable meridian to the place, and that degree on the equator which it cuts, is its longitude from London, in degrees and minutes, or that hour and minute is its longitude expressed in time.

Or if we bring the place to the strong brass meridian, that will cut the equator in the longitude as before.

Thus Boston in new England is about 70½ degrees west of London; Cape Comorin in the East Indies 282° west of London; or the longitude of the first place expressed in time is 4 h. 42 min. of the second 18 h. 48 min.

143. The method of reckoning longitude always westward from the first meridian is most natural, because it is agreeable to the real motion of the earth;

But the common method is to reckon it half round the globe eastward, and the other half westward from the first meridian, ending either way at 180 degrees.

Thus Cape Comorin is 78 degrees east of London.

Note. The numbers nearest the equator increase westward from the meridian of London quite round the globe to 360, over which another set of numbers is engraved, which increase the contrary way, by which means the longitude may be reckoned upon the equator either east or west.

144. It is mid-day or noon to all places in the same meridian at the same time.

Thus London, Oran, Cape Coast-castle in the Mediterranean, and Mundfort on the Gold-coast, have their noon nearly at the same time; Boston in New England about 4 h. 42 min. later; and Cape Comorin 18 h. 48 min. later.

145. The difference of longitude of any two places, is the quantity of an angle at the pole made by the meridians of those places; which angle is measured upon the equator.

To express this angle upon the Globe.

146. Bring the moveable meridian to one of the places, and the other place under the strong brass circle, they then contain the required angle; the

measure or quantity of which is the number of degrees counted on the equator between these two brass meridians.

PROBLEM VIII. *To find what places have mid-day, or the sun, upon their meridian, at any given hour of the day in any place proposed.*

147. First, let the hour proposed be X o'clock in the morning at London.

As the real diurnal motion of the earth, here represented by the terrestrial globe, is from west to east,

All places to the eastward of any particular meridian must necessarily pass by the sun, before the meridian of any other place to the westward of that particular meridian can arrive at it.

148. And therefore as the first meridian on our new terrestrial globe passes through London, if the proposed place be London, as in this case, bring the given hour, which is placed on our globes, to the east of London if it be in the morning, but to the west of London if it be in the afternoon, to the graduated side of the strong brass meridian; and all those places which lie directly under it, have noon, or the sun, upon their meridian, when it is X o'clock at London.

Thus having brought the Xth hour on the equator to the eastward of London under the divided side of the strong brass meridian, it will be found to pass over the eastern side of Lapland, and the eastern extremity of the Gulf of Findland, Petersburgh in Russia, to cross a part of Moldavia and the Black Sea, thence it passes over a part of Turkey, and goes between the islands of Candia and Cyprus in the Mediterranean, thence over the middle of Egypt through the eastern side of Africa, and across the bay of Lorenzo; all which places have the sun on their meridian when it is X o'clock in the morning at London.

149. Secondly, Let the hour proposed be IV o'clock in the afternoon at Port-Royal in Jamaica.

Bring Port Royal in Jamaica to the strong brass meridian, and set the horary index to that XII which is most elevated; then turn the globe from west to east, until the horary index points to IV o'clock, and the strong brass meridian will pass over the western side of the Isle Pasares in the Pacific Ocean, and the eastern side of the isle La Messa, thence it crosses the equator, and passes nearly over the islands Mendoca and Dominica, which places have the sun on their meridian when it is IV o'clock in the afternoon at Port-Royal in Jamaica.

150. Thirdly, Let the proposed hour be 30 min. past V o'clock in the morning at Cape Pasaro in the island of Sicily.

Bring Cape Pasaro to the strong brass meridian, set the horary index to that XII which is most elevated, and turn the globe westward, because the proposed time is in the morning, till the horary index points to 5 h. 30 min. and you'll find the strong brass meridian to pass over the middle of Siberia, Chinese Tartary, the kingdom of China, Canton in China, the middle of the island of Borneo, &c. at all which places it is noon, (they having the sun upon their meridian at the same time) when it is half an hour past V o'clock in the morning at Cape Pesaro in Sicily.

PROBLEM IX. *To find what hour it is at any place proposed when it is noon at any given place.*

151. Bring the proposed place under the strong brass meridian, and set the horary index to XII, then turning the globe, bring the given place to the meridian, and the hour required will be shewn by the horary index upon the equator. If the proposed place be to the eastward of the given place, the answer will be, afternoon; but if to the westward of it, the answer is, before noon.

Thus when it is noon at London, it is 49 minutes past XII at Rome, and 32 minutes past VII in the evening at Canton in China, and also 15 minutes past VII o'clock in the morning at Quebec in Canada, and this at one and the same instant of time.

PROBLEM X. *At any given time of the day in the place where you are, to find the hour at any other place proposed.*

152. Bring the proposed place under the strong brass meridian, and set the horary index to the given time; then turn the globe till the place where you are is under the brass meridian, and the horary index will point to the hour and minute required.

Thus suppose we are at London at IX o'clock in the morning, what time of the day is it then at Canton in China? Answer, 31 minutes past IV in the afternoon.

Also, when it is IX in the evening at London, it is about 15 minutes past IV o'clock in the afternoon at Quebec in Canada.

Problem XI. *The latitude and longitude of any place being known, to find that place upon the globe; or if it be not inserted, to find its place, and fix the center of the artificial horizon thereon.*

153. The latitude of Smyrna in Asia is 38 deg. 28 min. north, its longitude 27 deg. 30 min. east of London.

Bring 27 deg. 30 min. on the equator counted eastward of our first meridian to the strong brass circle, and under 38 deg. 28 min. on the north side of the equator, you will find Smyrna.

The latitude of Cape Lorenzo in Peru is 1 deg. 2 min. south, and longitude 80 deg. 17 min. west of London: this place is not inserted upon the globe. Therefore bring the graduated edge of the moveable meridian to 80 deg. 17 min. counted westward on the equator, and slide the diameter of the artificial horizon to 1 deg. 2 min. south; and its center will be correctly placed on that point of the globe, where the Cape of Lorenzo ought to have been placed.

The four last problems depend entirely on the knowledge of the longitude and difference of longitude of places.

THE ECLIPTIC EL

154. Is that graduated circle which crosses the equator in an angle of about 23½ degrees; and this angle is called the obliquity of the ecliptic.

This circle is divided into 12 equal parts, each of which contains 30 degrees; the beginning of each 12th part is marked with the usual characters, which with their names are as follow;

0	1	2	3	4	5	6
Aries,	Taurus,	Gemini,	Cancer,	Leo,	Virgo,	Libra.
♈	♉	♊	♋	♌	♍	♎

7	8	9	10	11
Scorpio,	Sagittarius,	Capricornus,	Aquarius,	Pisces.
♏	♐	♑	♒	♓

By these the twelve signs are represented upon the terrestrial globe. Upon our celestial globe, just under the ecliptic, the months, and days of each month, are graduated, for the ready fixing the artificial sun upon its place in the ecliptic.

The sun's apparent place is always in this circle; he advances therein every day about 59 min. 8 sec. of one degree, and seems to pass through it in a tropical year.

155. Those two points, where the ecliptic crosses the equator, are called equinoctial points, and are marked with these charrcters ♈ and ♎ at the beginning of Aries and Libra.

The first of these is called the vernal, the second the autumnal, equinox.

156. The first degree of Cancer and Capricorn is marked with the characters ♋ and ♑, which two points are called the solstices; the first is the summer solstice, the second that of the winter, to all the inhabitants upon the north side of the equator; but directly contrary to those on the south side of it.

Although the ecliptic does not properly belong to the earth, yet we have placed it upon our terrestrial globe according to ancient custom; it being useful in some particular cases; it is chiefly to be regarded upon the celestial globe.

157. The longitude of the stars and planets is reckoned upon the ecliptic; the numbers beginning

at the first point of Aries ♈, where the ecliptic crosses the equator, and increasing according to the order of the signs.

158. The latitude of the stars and planets is determined by their distance from the ecliptic upon a secondary or great circle passing through its poles, and crossing it at right angles.

159. Twenty-four of these circular lines, which cross the ecliptic at right angles, being fifteen degrees from each other, are drawn upon the surface of our celestial globe; which being produced both ways, those on one side meet in a point on the northern polar circle, and those on the other meet in a point on the southern polar circle.

160. The points determined by the meeting of these circles are called the poles of the ecliptic, one north, and other south.

161. The longitude of the stars hath been observed to increase about a degree in 72 years, which is called the precession of the equinox.

THE CELESTIAL SIGNS AND CONSTELLATIONS

162. On the surface of the celestial globe are represented by a variety of human and other figures, to which the stars that are either in or near them are referred.

The several systems of stars, which are applied to those images, are called constellations. Twelve of these are represented on the ecliptic circle, and extend both northward and southward from it. So many of those stars as fall within the limits of 8 degrees on both sides of the ecliptic circle, together with such parts of their images as are contained within the aforesaid bounds, constitute a kind of broad hoop, belt, or girdle, which is called the zodiac.

The names and the respective characters of the twelve signs of the ecliptic may be learned by inspection on the surface of the broad paper circle; and the constellations from the globe itself.

163. The zodiac is represented by eight circles parallel to the ecliptic, on each side thereof; these circles are one degree distant from each other, so that the whole breadth of the zodiac is 16 degrees.

164. Amongst these parallels, the latitude of the planets is reckoned; and in their apparent motion they never exceed the limits of the zodiac.

165. On each side of the zodiac, as was observed, other constellations are distinguished; those on the north side are called northern, and those on the south side of it, southern constellations.

166. All the stars which compose these constellations are supposed to increase their longitude continually; upon which supposition, the whole starry firmament has a slow motion from west to east; insomuch that the first star in the constellation of Aries, which appeared in the vernal intersection of the equator and ecliptic in the time of Meton the Athenian, upwards of 1900 years ago, is now removed about 30 degrees from it.

To represent this motion upon the celestial globe, elevate the north pole, so that its axis may be perpendicular to the plane of the broad paper circle, and the equator will then be in the same plane; let these represent the ecliptic, and then the poles of the globe will also represent those of the ecliptic; the ecliptic line upon the globe will at the same time represent the equator, inclined in an angle of 23½ degrees to the broad paper circle, now called the ecliptic, and cutting it in two points, which are called the equinoctial intersections.

Now if you turn the globe slowly round upon its axis from east to west, while it is in this position, these points of intersection will move round the same way; and the inclination of the circle, which in shewing this motion represents the equinoctial, will not be altered by such a revolution of the intersecting or equinoctial points. This motion is called the precession of the equinoxes, because it carries the equinoctial points backwards amongst the fixed stars.

The poles of the world seem to describe a circle from east to west, round the poles of the ecliptic, arising from the precession of the equinox. This motion of the poles is easily represented by the above position of the globe, in which, if the reader remembers, the broad paper circle represents the ecliptic, and the axis of the globe being perpendicular thereto represents the axis of the ecliptic; and the two points, where the circular lines meet, described in Art. 159, 160, will now represent the poles of the world, whence as the globe is slowly turned from east to west, these points will revolve the same way about the poles of the globe, which are here supposed to represent the poles of the ecliptic. The axis of the world may revolve as above, although its situation with respect to the ecliptic be not altered; for the points, here supposed to represent the poles of the world, will always keep the same distance from the broad paper circle, which represents the ecliptic in this situation of the globe.*

* RUTHERFORTH's System of Nat. Phil. vol. II. p. 730.

167. From the different degrees of brightness in the stars, some appear to be greater than others, or nearer to us; on our celestial globe, they are distinguished into seven different magnitudes.

GENERAL PHŒNOMENA ARISING FROM THE EARTH'S DIURNAL MOTION.

168. The daily rotation of the earth about its axis is one of the most essential points which a beginner ought to have in view; for every particular meridian thereon is successively turned towards every point in the heavens, and as it were describes circles in the celestial sphere, perpendicular to the axis of the earth, and parallel to each other; by which means the fixed stars seem to have an apparent diurnal motion,

169. Except those two points in the starry firmament, into which the earth's axis, supposed to be so far extended, would fall; these two points are called the celestial poles, which correspond with our terrestrial north and south poles.

170. We have so contrived our new globes that the real diurnal motion of the earth and the apparent diurnal motion of the heavens are represented by them Art. 85, 86, and thence all problems solved as readily in south as in north latitudes, and in places on or near the equator; by which means we are enabled to shew, how the vicissitude of days and nights, their various alterations in length, the duration of the twilight, &c. are really made by the earth's daily motion, upon the principles of the Pythagorean or Copernican system.

In fig. 26, ÆNQSÆ represent the apparent concave sphere of the fixed stars, æ n q s æ the globe of the earth, whose axis n s is supposed to be extended to N S, in the sphere of the fixed stars; all the stars seem to revolve upon these two points as poles.

If the plane of the earth's equator æ z q c æ is conceived to be extended to the starry firmament, it will point out the celestial equator Æ ♎ Q ♈ Æ.

N represents the celestial, and n the terrestrial north pole, S and s the south pole.

PARALLELS OF LATITUDE, DECLINATION, TROPICS, AND POLAR CIRCLES.

171. Fig. 26. That circle which any star seems to describe in twenty-four hours is called its parallel: thus, suppose a right line drawn from C the center of the earth, through any point d of its surface, and extended to D in the starry firmament, by means of the earth's daily rotative motion, the extremity D of the line C D will describe the celestial parallel G x D x G, corresponding to the terrestrial parallel g d, of the point d. If D C be supposed to be extended to H, the opposite side of the starry firmament, it will describe another parallel equal to the former.

Those circular lines upon the terrestrial globes, which are described from the poles, on either side of the equator, are parallel to it, and are called parallels of latitude, but on the celestial globe they are called parallels of declination.

There are four principal lesser circles parallel to the equator, which divide the globe into five unequal parts called Zones; these are the two tropics, and the two polar circles.

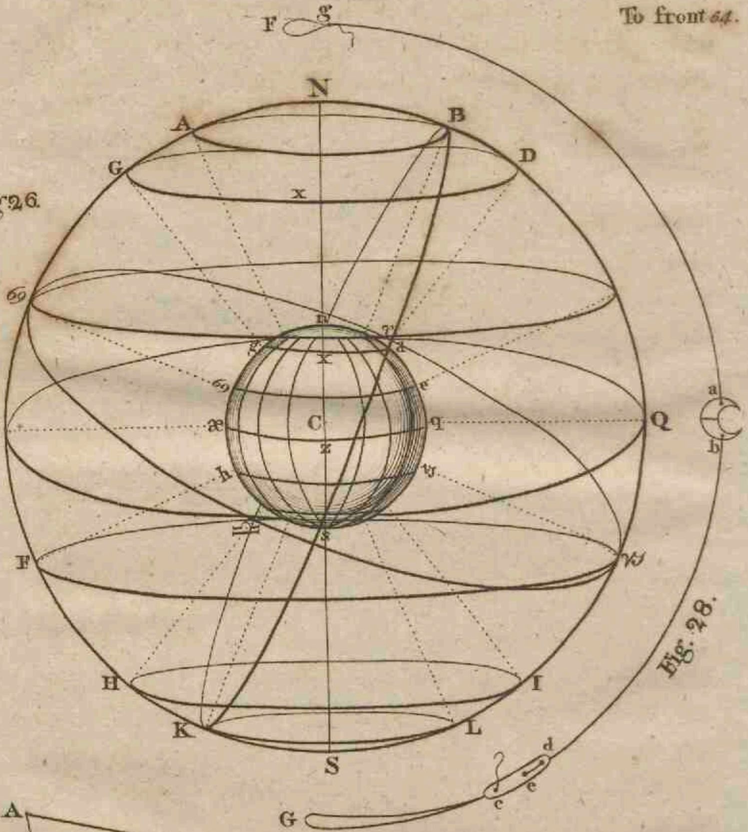


Fig. 26

Fig. 28.

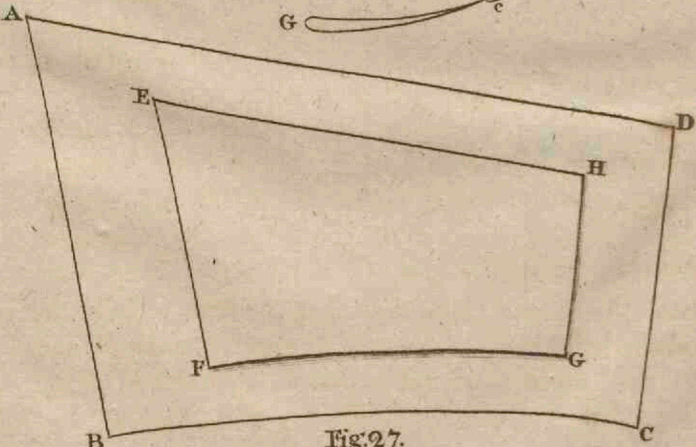


Fig. 27.

We have already shewn, that the distance of any parallel from the equator, measured in the arch of a great circle on the terrestrial sphere, is its latitude; and on the celestial sphere, its declination, Art. 135.

172. If the sun, moon, a fixed star, or planet, is situated in any parallel between the equator Æ Q, fig. 26, and the north pole N, it is said to have north declination; but if towards the south pole S, south declination.

Thus the two parallels G D, and H I, have the same declination: because they are equally distant from Æ Q the equator; the first hath north, the last south declination.

Hence we must observe, that a celestial parallel G X D, and its correspondent g x d upon the earth, are two parallel circles, being similar elements of a cone, whose axis is that of the earth, and apex C, the center of the earth. Therefore the plane of a terrestrial parallel cannot be the same with its correspondent celestial parallel; only the plane of the celestial equator Æ ♎ Q ♈ Æ, is the same with that of the terrestrial æ z q, because these two planes are produced by the same radius C Q, perpendicular to the axis N S, on which the earth or the heavens are supposed to turn.

If by the earth's daily rotative motion, a star D passes over the zenith d of any inhabitant of the earth, that star is the celestial parallel, which corresponds to the terrestrial parallel of the observer; for the distance of the celestial parallel G D, contains the same number of degrees from Æ Q, the celestial equator, as that of the inhabitant's parallel g d does from æ q, the terrestrial equator.

Therefore the measure of the arch of any inhabitant's distance from the terrestrial equator, which is called the latitude of the place, is similar and equal in the number of degrees, to that fixed star's declination, which passes over his zenith.

If the inhabitant changes his situation either north or south, the different declinations of those stars which pass over his zenith, at the several places of his removal, will shew his advance towards or regress from the equator.

Whence any place upon the earth may be represented by its corresponding zenith point, in the apparent concavity of the starry sphere; as shall be hereafter shewn.

173. Upon our new terrestrial globe, there are twenty-three parallels drawn at the distance of one degree from each other, on both sides the equator; which, with two other parallels at 23½ degrees distance, include the ecliptic circle; these two are called the tropics. That on the north side of the equator is called the tropic of Cancer; and the other, which is on the south side of it, the tropic of Capricorn.

174. The space between these two tropics, which contains about 47 degrees, was called by the ancients, the torrid zone.

The two polar circles are placed at the same distance from the poles, that the two tropics are from the equator.

One of these is called the northern, the other the southern polar circle.

These include 23½ degrees on each side of their respective poles, and consequently contain 47 degrees, equal to the number of degrees included between the tropics.

175. The space contained within the northern polar circle, was by the ancients called the north frigid zone, and that within the southern polar circle, the south frigid zone.

176. The spaces between either polar circle, and its nearest tropic, which contain about 43 degrees each, were called by the ancients the two temperate zones.

177. Whenever any parallel passes through two places on the terrestrial globe, these places have the same latitude.

Also all those stars which are in the same parallel upon the celestial globe, have the same declination.

And as the ecliptic is inclined to the equator in an angle of 23½ degrees, and is included between the tropics, every parallel in the torrid zone must necessarily cross the ecliptic in two places; which two points shew the sun's place, when he is vertical to the inhabitants of that parallel; and the days of the month upon the broad paper circle answering to those points of the ecliptic, are the days on which the sun passes directly over their heads at noon, and are called their two midsummer days: whence the inhabitants of the torrid zone have two summers and two winters every year.

Hence as the earth's progressive, or rather apparent annual motion, seems to be in the celestial ecliptic, the sun's declination is thereby changed gradually every day. Therefore on our new terrestrial globe, as mentioned in Art. 173, we have drawn parallels through the whole space of the torrid zone, and the two spaces within the polar circles, to give a general and clear idea of the sun's apparent passage from one tropic to another.

THE COLURES

178. Are circular lines drawn on the celestial globe from pole to pole, (as meridians are upon the terrestrial globe) crossing the equator at right angles, and being secondaries to it. Art. 140.

179. The two celestial meridians which pass through the first point of ♈ and ♎ making together one great circle, are represented by the circle B ♈ K ♎ B, in fig. 26, and are called the equinoctial colure. The points marked ♈ and ♎ are called the equinoxes, or equinoctial points.

180. The two celestial meridians represented by the circle N Æ S Q N, passing through the solstitial points (marked ♋ and ♑) of Cancer and Capricorn, are called the solstitial colure.

181. These colures cut each other at right angles in the poles of the world, and divide the celestial equator, ecliptic, and zodiac, into four equal parts, which points determine the four seasons of the year. See Art. 34 to 41, and Art. 187.

The equinoctial colure only passes through the poles of the world at n and s. But,

The solstitial colure passes through the poles of the world at n and s, and also through the poles of the ecliptic at B and K, fig. 26.

Whence it happens in every daily rotation of the earth about its axis, that the solstitial and equinoctial colures are twice blended with every meridian upon the surface of the earth: consequently, each pole of the ecliptic appears to pass, once every day, over all the meridians of the terrestrial sphere.

182. All those circular lines that are, or may be supposed, drawn on the celestial globe, which pass through the poles, cutting the equator at right angles, are called circles of declination; because the declination of those points or stars through which they pass, or the distance of those stars from the equator, is measured upon these circles: and this is done by bringing the divided edge of the moveable meridian to any star.

Hence the thin brass semi-circle, Art. 115, which we call the moveable meridian, is also a moveable circle of declination.

ARCTIC AND ANTARCTIC CIRCLES, OR CIRCLES OF PERPETUAL APPARITION AND OCCULTATION.

183. The largest parallel of latitude on the terrestrial globe, as well as the largest circle of declination on the celestial, that appears entire above the horizon of any place in north latitude, was called by the ancients the arctic circle, or circle of perpetual apparition.

Between the arctic circle and the north pole in the celestial sphere, are contained all those stars which never set at that place, and seem to us, by the rotative motion of the earth, to be perpetually carried round above our horizon in circles parallel to the equator.

The largest parallel of latitude on the terrestrial, and the largest parallel of declination on the celestial globe, which is entirely hid below the horizon of any place, were by the ancients called the antarctic circle, or circle of perpetual occultation.

This circle includes all the stars which never rise in that place to an inhabitant of the northern hemisphere, but are perpetually below the horizon.

All arctic circles touch their horizons in the north point, and all antarctic circles touch their horizons in the south point; which point, in the terrestrial and celestial spheres, is the intersection of the meridian and horizon.

If the elevation of the pole be 45 degrees, the most elevated part either of the arctic or antarctic circle, will be in the zenith of the place.

If the pole's elevation be less than 45 degrees, the zenith point of those places will fall without its arctic or antarctic circle. If greater, it will fall within.

Therefore the nearer any place is to the equator, the lesser will its arctic and antarctic circles be; and on the contrary, the farther any place is from the equator, the greater they are. So that,

At the poles, the equator may be considered as both an arctic and antarctic circle, because its plane is coincident with that of the horizon.

But at the equator (that is, in a right sphere) there is neither arctic nor antarctic circle.

They who live under the northern polar circle, have the tropic of Cancer for their arctic, and that of Capricorn for their antarctic circle.

And they who live on either tropic, have one of the polar circles for their arctic, and the other for their antarctic circle.

Hence, whether these circles fall within or without the tropics, their distance from the zenith of any place is ever equal to the difference between the pole's elevation, and that of the equator above the horizon of that place.

From what has been said, it is plain, there may be as many arctic and antarctic circles, as there are individual points upon any one meridian, between the north and south poles of the earth.

184. Many authors have mistaken these mutable circles, and have given their names to the immutable polar circles, which last are arctic and antarctic circles, in one particular case only, as has been shewn.

THE CAUSE OF THE DAILY CHANGE IN THE DECLINATION OF THE SUN,

185. Arises from the earth's annual motion in the ecliptic, the inclination of its axis, and its always moving parallel to itself.

Imagine the plane of the earth's orbit extended as far as the fixed stars, it will there mark out the circle ♋, ♎, ♑, ♈, ♋, which we call the celestial ecliptic; see fig. 26.

From this comparison of the earth's orbit with the celestial ecliptic, is derived the ancient rule to find the sun's place, if we first find the earth's place, either by observation or calculation; six signs added to or subtracted from it gives the sun's true place in the ecliptic. Consequently it is the same when we consider the daily motion of the earth about her equatorial axis, represented by the terrestrial globe, whether we suppose the earth, or the sun, to have an annual motion.

It is also the same thing in the use of the celestial globe, whether we suppose the earth to turn upon her equatorial axis, or the starry sphere to revolve upon the extremities of the same axis extended to the heavens: the result in either case will be the same, provided we conceive ourselves at the center of the globe.

186. We shall therefore suppose the sun's apparent annual motion to be in the plane of the celestial ecliptic, Art. 34 to 41, and in his passage through it, describing by a ray connecting the centers of the earth and sun, a different circle of declination, parallel to the equator every day. Whereby all who inhabit any of those places on the earth which are situated between the terrestrial tropic of Cancer represented in fig. 26, by ♋, e, and the terrestrial tropic of Capricorn represented by b, ♑, have the sun at the time he is describing their parallel, in their zenith; or directly vertical, or over their heads, which happens twice every year.

187. Whence the inhabitants of those places, as well as mariners who pass between the tropics, have a corresponding zenith point, where their latitude is equal to the sun's parallel of declination, from the sun by day, and from the stars by night.

It is easily conceived, that if the planes of the equator and ecliptic were united in one continued plane, a central solar ray, connecting the centers of the earth and sun, would by the earth's diurnal motion describe the equator every day; but, as we have before observed, the sun does apparently de-describe a different parallel every day: wherefore the ecliptic and equator are inclined to each other in an angle confirmed by observation of about 23 deg. 29 min.

Let the sun's apparent annual motion be represented by the circle ♋, ♎, ♈, ♋, fig. 26, which ♑, ♈, ♋, bisects the celestial equator Æ ♎ Q ♈ Æ in the points ♎ and ♈; the first of these is called the autumnal, the second the vernal, equinoctial point.

When the sun is in ♎, he appears to describe the equator, at which time he has no declination; and as he proceeds gradually from ♎ towards ♑, his southern declination continually increases, and he describes less and less parallels, till he appears in ♑, and describes the tropic of Capricorn; being then at his greatest southern declination, viz. at his greatest distance from the equator southerly, and also in the winter solstice.

In passing from ♑ to ♈, his declination decreases, and the parallels he describes are greater and greater, until he comes to Aries, or the vernal equinox, and again has no declination, describing the equator as before.

As he advances from thence towards ♋, the declination increases, and the parallels described are less and less, until he arrives at ♋, or the summer solstice; being then at his greatest northern declination, describing the tropic of Cancer.

Thence proceeding forwards towards ♎, the declination continually decreases, and the parallels described increase till the sun's arrival at the next succeeding autumnal equinox; where he again describes the equator, having no declination; and completes the length of a mean solar tropical year, containing 365 d. 5 h. 49 min.

What we have said with respect to summer and winter solstices, is to be understood with relation to those places which lie between the equator and the north pole; but to the places between the equator and south pole the contrary happens.

The two equinoxes are the same to all the inhabitants of the earth.

We have been thus particular in our description of the sun's apparent annual motion, for the use of beginners; and we hope this consideration will plead in our behalf, if we should appear tedious or trifling to those who are masters of the subject.

But what has been said, might yet be more clearly illustrated by an orrery or a tellurian, which shews the annual and diurnal motions of the earth, and parallelism of its axis, &c. and by the different positions of the earth's axis, with respect to her enlightened disc, will make it appear to the eye as it is really understood by astronomers; and then we may with more propriety repair to the use of the globe itself.

TO SUPPLY THE WANT OF A TELLURIAN.

188. Describe a circle A B C D, fig. 8, with chalk upon the floor, as large as the room will admit of, that the globe may be moved round upon it: divide this circle into twelve parts, and mark them with the characters of the twelve signs, as they are engraved in fig. 8, or upon the broad paper circle; placing ♋

at the north, ♑ at the south, ♈ in the east, and ♎ in the west: the mariner's compass under the globe will direct the situation of these points, if the variation of the magnetic needle be attended to.

Note. At London the variation is between 20 and 21 degrees from the north westward.

Elevate the north pole of the globe, so that 66½ degrees on the strong brass meridian may coincide with the surface of the broad paper circle, and this circle will then represent the plane of the ecliptic, as mentioned in Article 103.

Set a small table or stool over the center of the chalked circle to represent the sun, and place the terrestrial globe upon its circumference over the point marked ♑, with the north pole facing the imaginary sun, and the north end of the needle pointing to the variation: this is the position of the earth with respect to the sun at the time of the summer solstice about the 21st of June: and the earth's axis, by this rectification of the globe, is inclined to the plane of the large chalked circle, as well as to the plane of the broad paper circle, in an an angle of 23½ degrees; a line or string passing from the center of the imaginary sun to that of the globe, will represent a central solar ray connecting the centers of the earth and sun: this ray will fall upon the first point of Cancer, and describe that circle, shewing it to be the sun's place upon the terrestrial ecliptic, which is the same as if the sun's place, by extending the string, was referred to the opposite side of the chalked circle, here representing the earth's path in the heavens.

If we conceive a plane to pass through the axis of the globe, it will also pass through the sun's center, and the points of Cancer and Capricorn in the terrestrial and celestial ecliptic; the central solar ray in this position of the earth is also in that plane; this can never happen but at the times of the solstice.

If another plane be conceived to pass through the center of the globe at right angles to the central solar ray, it will divide the globe into two hemispheres; that next the center of the chalked circle will represent the earth's illuminated disc, the contrary side of the same plane will at the same time shew the obscure hemisphere.

The intelligent reader, for the use of his pupils, may realize this second plane by cutting away a semicircle from a sheet of card paste-board, with a radius of about 1½ tenth of an inch greater than that of the goble itself; if this plane be applied to 66½ degrees upon the strong brass meridian, it will be in the pole of the ecliptic; and in every situation of the globe round the circumference of the chalked circle, it will afford a lively and lasting idea of the annual and diurnal motion of the earth, of the various phænomena arising from the parallelism of the earth's axis, and in particular the daily change of the sun's declination, and the parallels thereby described.

Let the globe be removed from ♑ to ♒, and the needle pointing to the variation as before will preserve the parallelism of the earth's axis; then it will be plain, that the string or central solar ray will fall upon the first point of Leo, six signs distant from, but opposite to the sign ♒, upon which the globe stands: the central solar ray will now describe the 20th parallel of north declination, which will be about the 23d of July.

If the globe be moved in this manner from point to point round the circumference of the chalked circle, and care be taken at every removal that the north end of the magnetic needle, when settled, points to the degree of the variation, the north pole of the globe will be observed to recede from the line connecting the centers of the earth and sun, until the globe is placed upon the point Cancer: after which, it will at every removal tend more and more towards the said line, till it comes to Capricorn again.

PROBLEM XII. *To rectify either globe to the latitude and horizon of any place.*

189. If the place be in north latitude, raise the north pole; if in south latitude, raise the south pole, until the degree of the given latitude, reckoned on the strong brass meridian under the elevated pole, cuts the plane of the broad paper circle; then this circle will represent the horizon of that place.

To rectify for the sun's place.

190. After the former rectification, bring the degrees of the sun's place in the ecliptic line upon the globe to the strong brass meridian, and set the horary index to that XIIth hour upon the equator which is most elevated.

191. Or, if the sun's place is to be retained, to answer various conclusions, bring the graduated

edge of the moveable meridian to the degree of the sun's place in the ecliptic, upon the celestial globe, and slide the wire which crosses the center of the artificial sun thereto: then bring its center, which is the intersection of the aforesaid wire, and graduated edge of the moveable meridian, under the strong brass meridian as before, and set the horary index to that XII on the equator which is most elevated.

To rectify for the zenith of any place.

192. After the first rectification, screw the nut of the quadrant of altitude so many degrees from the equator, reckoned on the strong brass meridian towards the elevated pole, as that pole is raised above the plane of the broad paper circle, and that point will represent the zenith of the place.

Note. The zenith and nadir are the poles of the horizon, the former being a point directly over our heads, and the latter, one directly under our feet.

193. If you are doubtful whether the proper point of the brass meridian is correctly cut, when set by the eye, apply a card cut in the shape of fig. 27, to the place, flat upon the broad paper circle, and it will be truly adjusted.*

If, when the globe is in this state, we look on the opposite side, the plane of the horizon will cut the strong brass meridian at the complement of the latitude, which is also the elevation of the equator above the horizon.

* See the Advertisement at the end of the Preface.

PROBLEM XIII. *To find the moon's mean place upon the celestial globe, her age and day of the month being known.*

194. The moon increases her longitude in the ecliptic every day about 13 deg. 10 min. by which means she crosses the meridian of any place about 50 minutes later than she did the preceding day.

Thus if her place be in the 12th degree of Taurus any day at noon, it will be 25 deg. 10 min. in Taurus on the succeeding noon.

It is new moon when the sun and moon have the same longitude, or are in or near the same point of the ecliptic.

When they have opposite longitudes, or are in opposite points of the ecliptic, it is full moon. Art. 56 to 64.

To perform the problem tolerably near the truth, without having recourse to an ephemeris, which may not always be at hand,

Find the day of the new moon next preceding the given day of the month in any common almanack, the number of days elapsed is the moon's age.

The equator on our new celestial globe is divided by large dots into 29½ equal parts, each of which is directed by a short dotted line, to a number marked in Roman figures, expressing the several days of the moon's age.

THE RULE.

195. Elevate the north pole of the celestial

globe to 90 degrees, and then the equator will be in the plane of, and coincide with the broad paper circle; bring the first point of Aries, marked ♈ on the globe, to the day of the new moon on the said broad paper circle, which answers to the sun's place for that day; and the day of the moon's age will stand against the sign and degree of the moon's mean place; to which set the artificial moon upon the ecliptic on the globe.

But if you are provided with an ephemeris,* that will give the moon's latitude and place in the ecliptic; first note her place in the ecliptic upon the globe, and then counting so many degrees amongst the parallels in the zodiac, either above or below the ecliptic, as her latitude is north or south upon the given day, and that will be the point which represents the true place of the moon for that time, to which apply the artificial moon.

196. *Note.* The artificial moon is a small thin piece of brass in form of a crescent, having two holes a and b, fig. 28, through which a small string of silk twist is put, that it may slip backwards or forwards upon it.

To one end c of this silk string is tied a small piece of brass d e c with three holes at d e c.

The manner of putting it upon the globe is this: first put the crescent a b, on the string; and the piece of brass, by passing the string through the two holes d, e, the string being as yet left free. The two ends of the string being loose, pass the end F round the north pole of the globe, in a groove made for that purpose, and tie it into a loose loop like F g, then put the other end of the

* The Nautical Almanack is the best English Ephemeris extant.

string G c round the south pole, and tie it fast to the hole at c: then by pulling the piece d e c upwards, the string may be tightened on any part of the globe, and pushing it downwards will slacken it, that it may be removed to any other place, and then tightened again.

PROBLEM XIV. *To represent the apparent diurnal motion of the sun, moon, and stars, on the celestial globe.*

197. Find the sun's place in the ecliptic, by Problem i. Art. 98, and to that point on the ecliptic line which is drawn upon the globe, set the center of the artificial sun. Also,

Find the moon's place by Problem xiii. Art. 194. and set the center of the artificial moon upon it.

Rectify the globe to the latitude, sun's place, and zenith, by Problem xii. Art. 189, 190, and 192.

The globe being turned round its axis from east to west, will represent the apparent motion of the sun, moon, and stars, for that day.

198. When the center of the artificial sun is in the plane of the horizon on the eastern side, the horary index shews upon the equator the time of sun rising.

199. All those stars which are then in the plane of the horizon on the eastern side, are at the same instant of time rising with the sun, and those on the western side of the horizon, are then setting.

Their distance from the true east or west points of the horizon, is called the sun or star's amplitude.

200. And when the center of the artificial moon comes to the horizon on the eastern side, the horary index will point to the hour and minute of her rising.

And those stars on the eastern edge of the horizon are then rising with her, whilst at the same time all the stars, cut by the western edge, are setting.

201. That degree and minute of the equator which is cut by the plane of the horizon, at the same time that the center of the artificial sun, moon, or any star, is also cut by the said plane, is the very point of the equator, which rises with either of them, and is called the sun, moon, or star's oblique ascension.

202. As the sun ascends in the heavens till it culminates, or comes under the graduated side of the strong brass meridian, the horary index will successively point to the hours before noon; but when it is under it, the horary index points at XII o'clock, and that degree and minute on the equator, which is then cut by the brass meridian, is called the sun's right ascension, that is, its distance from the first point of Aries, reckoned in degrees, minutes, &c. upon the equator.

203. At the same time, that degree of the brass meridian, which is directly over the artificial sun, is his declination, Art. 133, for that day.

The same is to be observed of the moon or any star, as they ascend in the heavens, till they culminate or come under the meridian, the horary index constantly pointing to the hour of the day or night; their right ascension and declination are also shewn in the same manner as that of the sun.

204. Whilst the sun descends from the meridian westward, the horary index successively shews the hours after noon.

And when the center of the artificial sun is in the plane of the horizon on the western side, the horary index shews the time of sun setting; and that point of the equator which is then cut by the plane of the horizon, is the point which sets with the sun, and is called his oblique descension.

205. The number of degrees on the equator contained between the points of his oblique ascension, and right ascension, or between the points of his right ascension, and oblique descension, is called his ascensional difference.

Observe the same with respect to the moon or any star: as they descend from the meridian westward, the horary index will successively shew the time of their arrival at any given point, their setting, oblique descension, and ascensional difference, in the same manner as before described in relation to the sun.

The rising, culminating, setting, &c. of any planet may be obtained, if the place of the planet, its longitude and latitude being taken from an ephemeris, be ascertained; and an artificial planet set thereto, in the manner in which we have directed the artificial moon to be placed upon the globe, Art. 196, or this last may occasionally represent a planet.

Thus on the 18th day of June, A. D. 1769 new stile, being the first year after bissextile, the sun's place will be ♊, 27 deg. 22 min. the moon's place ♐, 18 deg. 0 min. her latitude north 0 deg. 30 min. The full moon about ¼ of an hour past VIII o'clock in the morning; to which places, if the artificial sun and moon be set, a beginner may readily exercise himself in finding the proper answers agreeable to these data, by the directions in this problem.

PARALLELS OF ALTITUDE.

206. The globe remaining rectified as in the last problem, the uppermost point represents a point in the heavens directly over our heads, which is called the zenith: and as the brass quadrant is moveable about its upper end as a center, when that center is fixed to the latitude of the place upon the strong brass meridian, it will be in the zenith, and the beginning of its graduations will coincide with the plane of the broad paper circle, which in these cases represents the horizon of the place.

If the quadrant be moved about the globe, its first division will describe the horizon. And,

At the same time, all its intermediate divisions will describe circles parallel to the horizon; the point marked 10 describes a parallel of 10 degrees, the point marked 20 a parallel of 20 degrees, and so of any other point.

207. These circles parallel to the horizon are called parallels of altitude, because they shew the elevation of the sun, moon, stars, or planets, above the plane of the horizon:

And the divisions on the quadrant itself in each case represent the distance of every secondary to the horizon.

PROBLEM XV. *To find the sun's altitude at any given time of the day.*

208. Set the center of the artificial sun to his place in the ecliptic upon the globe; and rectify it to the latitude and zenith, by Problem xii. Art. 189, &c.; bring the center of the artificial sun under the strong brass meridian, and set the hour index to that XII which is most elevated; turn the globe to the given hour, and move the graduated edge of the quadrant to the center of the artificial sun; and that degree on the quadrant which is cut by the sun's center, is the sun's height at that time.

The artificial sun being brought under the strong brass meridian, and the quadrant laid upon its center, will shew its meridian, or greatest altitude, for that day.

If the sun be in the equator, his greatest or meridian altitude is equal to the elevation of the equator, which is always equal to the co-latitude of the place.

AZIMUTH OR VERTICAL CIRCLES.

209. An azimuth circle in astronomy, is the very same as a circle of position in geography; they being secondaries to the horizon, or great circles passing through the zenith of any place, and crossing the horizon at right angles: either in the heavens, called azimuths: or on the earth, circles of position.

Any azimuth circle may be represented by the quadrant of altitude, when the center upon which it turns is screwed to that point of the strong brass meridian, which answers to the latitude of the place, and the place brought into the zenith.

Suppose at London, if you bring the divided edge of the quadrant to 10 degrees on the inner edge of the broad paper circle, it will represent an azimuth circle of 10 degrees; if you set it to 20, it will represent an azimuth circle of 20 degrees; and so of any other.

If the quadrant of altitude be set to 0 degree, that is either upon the east or west points of the broad paper circle, it will then represent that secondary to the horizon, or azimuthal circle, which is called the prime vertical.

PROBLEM XVI. *To find the azimuth of the sun, or any star.*

210. Rectify the globe to the latitude and sun's place, Art. 189, 190, then turn it to the given hour, and bring the divided edge of the quadrant of altitude to the sun's place in the ecliptic, or to the center of any star, and it will cross the horizon at the azimuth required.

The distance of that point of the horizon, in which the sun appears to rise or set, counted from the prime vertical, Art. 209, or east and west points of the horizon, is called the sun's amplitude.

COROLLARY. *To find the angle of position of places.*

211. The angle of position is that formed between the meridian of one of the places, and a great circle passing through the other place.

Rectify the globe to the latitude and zenith of one of the places, Art. 189, 192, bring that place to the strong brass meridian, set the graduated edge of the quadrant to the other place, and the number of degrees contained between it and the strong brass meridian, is the measure of the angle sought. Thus,

The angle of position between the meridian of Cape Clear in Ireland, and St. Augustine in Florida, is about 82 degrees north westerly; but the angle of position between St. Augustine and Cape Clear, is only about 46 degrees north easterly.

Hence it is plain, that the line of position, or azimuth, is not the same from either place to the other, as the romb-lines are.

COROLLARY. *To find the bearing of one place from another.*

212. The bearing of one sea-port from another is determined by a kind of spiral called a romb-line, passing from one to the other, so as to make equal angles with all the meridians it passeth by; therefore if both places are situated on the same parallel of latitude, their bearing is either east or west from each other; if they are upon the same

meridian, they bear north and south from one another; if they lie upon a romb-line, their bearing is the same with it; if they do not, observe to which romb-line the two places are nearest parallel, and that will shew the bearing sought.

Thus the bearing of the Lizard Point from the island of Bermudas is nearly E. N. E.; and that of Bermudas from the Lizard is W. S. W.; both nearly upon the same romb, but in contrary directions.

A PARALLEL SPHERE

213. Is that position of the globe, in which the poles are in the zenith and nadir, its axis at right angles to the equator and horizon, which coincide; and consequently those circles which are parallel to the equator, are also parallel to the horizon.

The inhabitants of this sphere, if any there be, must live upon the two terrestrial poles, and will have but one day and one night throughout the year; and the moon, during half her monthly course, will never rise, and during the other half will never set: all the fixed stars, visible to those people, will describe circles every day parallel to their horizon.

A RIGHT SPHERE

214. Is that in which the inhabitants see both poles in their horizon, the equator passing through their zenith and nadir, and all the circles parallel to the equinoctial perpendicular to their horizon.

These people live upon the terrestrial equator, consequently all the heavenly bodies will always rise and set perpendicularly to them; and their days and nights will be of an equal length throughout the year.

AN OBLIQUE SPHERE

215. Hath one of the poles of the globe above, the other under the horizon; the equator in all the cases of this sphere is half above, and half below the horizon, and all its parallel circles cut the horizon obliquely.

That arch of any parallel of declination in the celestial, or of latitude in the terrestrial sphere that is above the horizon, is called the diurnal arch. And

The remaining part of it, which is below the horizon, is called the nocturnal arch.

These arches, with respect to the sun's apparent motion, determine the different length of days and nights.

The inhabitants of this sphere are those who live on all parts of the earth, except those at the poles and upon the equator.

OF THE TWILIGHT.

That light which we have from the sun before it rises, and after it sets, is called the twilight.

216. The morning-twilight, or day-break, begins when the sun comes within 18 degrees of the horizon, and continues till sun-rising.

The evening twilight begins at the time of the sun-setting, and continues till it is 18 degrees below the horizon.

For this purpose on our new globes, a wire circle is fixed 18 degrees below the surface of the broad paper circle; so that

All those places which are above the wire circle will have the twilight, but it will be dark to all places below it.

At the time of winter solstice, when the whole space within the northern polar circle is out of the sun's light, the greater part of it enjoys the benefit of twilight; there being only about 5½ degrees round the pole that will be totally dark.

We have here only considered the twilight reflected to us from the earth's atmosphere by the sun himself; besides which the body of the sun is always encompassed with a sphere of light, which being of a larger circumference than the sun, must rise before him, and set after him; which consequently lengthens the twilight by illuminating our air, when the sun is depressed too low to reach it with his own light: this seems to be the cause, why the sun is preceded by a luminous segment of a circle in the east before his rising, different from that light reflected by the atmosphere from the body of the sun; the like to which may be observed in the west after sun-set.

TO REPRESENT THE EARTH'S ENLIGHTENED DISC BY THE TERRESTRIAL GLOBE.

217. We have already shewn how the earth's diurnal motion is represented by the motion of the

terrestrial globe about its axis from west to east; and that the horary index will point upon the equator the 24 hours of one diurnal rotation, or any part of that time.

The broad paper circle, under this consideration, will be now employed to represent a plane supposed to pass through the center of the earth, perpendicular to a central solar ray: or in other words, perpendicular to a line supposed to be drawn from the center of the sun to that of the earth at all times of the year.

In which case, the broad paper circle divides that half of the earth's surface, which is illuminated by the sun's rays, from the other hemisphere which is not enlightened.

218. That the globe may appear to be so enlightened, conceive a sun painted on the ceiling of the room in which you are, directly over the terrestrial globe, and of the same diameter; from whence imagine an infinite number of parallel rays falling perpendicularly downwards upon the upper surface of the globe, which here represents the illuminated hemisphere of the earth's enlightened disc.

Whence it is plain, that the central solar ray is the only one which passes through the centers of the sun and earth, as well as the only ray that can possibly be perpendicular to the earth's surface; all other solar parallel rays will fall more and more oblique, as they are farther from the central ray, till their arrival at the edge of the enlightened disc, here represented by the inner edge of the broad paper circle, where they will become parallel to the horizons of all places then under the said edge of the disc.

In one diurnal revolution of the earth, the central solar ray describes the parallel of the sun's declination; or rather that parallel, to the inhabitants of which the sun that day will pass directly vertical, or over their heads.

From this application of the terrestrial globe, we see the natural cause of the different altitudes of the sun at different times of the day, and at different seasons of the year; which arise from the earth's daily rotative and progressive motion, &c.

When we view the globe in this position, we at once see the situation of all places in the illuminated hemisphere, whose inhabitants enjoy the light of the day, while at the same time all those places below the broad paper circle are deprived of the sun's light, and have only twilight so far as the wire circle, and all below that, have total darkness, when the moon does not shine on them.

And by observing the angles made by the meridians, drawn on the globe, cutting any parallel of latitude at the edge of the broad paper circle, with the strong brass meridian, we see the semi-diurnal arches continually decrease from the elevated pole, till they come to the opposite part of the earth's enlightened disc.

PROBLEM XVII. *To rectify the terrestrial globe, that the enlightened half of the earth's surface may be all above the broad paper circle for any time of the year; the sun being supposed in the zenith.*

219. On the backside of the strong brass meridian, and on each side of the north pole, are graduated, in

two concentric spaces, the months and days of the year.

Bring the day of the month to coincide with the broad paper circle, and the terrestrial globe is rectified.

When the globe is thus rectified, that degree and minute upon the graduated side of the brass meridian, which is then cut by the plane of the broad paper circle, is the distance of the shade of extuberancy upon the earth's disc, reckoned from the pole, and is equal to the sun's declination for that day; and is therefore also equal to the latitude, counted from the equator, of all those places to which the sun is vertical; and this point on the brass meridian represents the central solar ray describing the parallel of the day.

If now the globe be turned from west to east, all those places which arrive at the western edge of the broad paper circle are passing out of the twilight into the sun's light; and the sun then appears rising to all the inhabitants.

At the same time, if you look upon the eastern edge of the broad paper circle, it will cut all those places which are then passing from the sun's light into the twilight; whose inhabitants will see the sun setting, and enjoy the twilight, until they arrive at the wire circle, which is placed 18 degrees below the illuminated disc, at which time they enter into total darkness.

The graduated side of the strong brass meridian shews, at the same time, all those places which have mid-day or noon.

If the horary index be set to XII, when any particular place is brought under the strong brass meridian, it will shew, as you turn the globe from west to east, the precise time of sun rising, setting, &c. at that place.

The horary index will also shew how long a place is moving from the west to the east side of the illuminated disc, here represented by the broad paper circle, and thence the length of the day and night; it will also point out the length of the twilight, by shewing the time in which the place is passing from the twilight circle to the edge of the disc on the western side, or from the edge of the disc to that circle on the eastern side; and thereby determining the length of its whole artificial day.

We shall proceed to exemplify these particulars at the times of equinox and solstice.

PROBLEM XVIII. *The time of equinox.*

220. The sun has no declination at the times of equinox, consequently there must be no elevation of the poles.

Bring the day of the month on the backside of the strong brass circle, in which the sun enters the first point of Aries or Libra, into the plane of the broad paper circle, and then the two poles of the globe will be in that plane also; and all those circles which are parallel to the equator will cut the plane of that broad circle at right angles, and the globe will then represent a right sphere.

If you now turn the globe from west to east, it will plainly appear, that all places upon its surface are twelve hours above the broad paper circle, and as many below it; which shews, that the nights are equal to the days to all the inhabitants of the earth; that is, they are illuminated by the sun's rays twelve hours: whence these are called the equinoctial seasons, two of which occur in every year; the first is the autumnal, the second the vernal equinox.

At these times the sun appears to rise and set at the same instant to all places in the same meridian.

But their twilight is longer as their situation is nearer to either pole; in so much that within 18 degrees of the poles, their twilight is twelve hours, consequently there is no dark night in those places at the times of equinox: when at the same time those places under the equator have only one hour and 12 minutes twilight; so that their artificial day is about 14h. 24m. at these two seasons of the year.

Thus, if London and Mundford on the Gold Coast, be brought to the strong brass meridian, the graduated side of which is in this case the horary index; (though in other cases the hour index is to be set to that XII which is most elevated;) if then they be brought to the west side of the broad paper circle, the index will point to VI o'clock for sun-rising, and to VI for sun setting, when these places are brought to the eastern side.

Also, if London be turned from the west towards the east, and the hour index be set to XII as before, if you turn it till the island of Jamaica comes to the meridian, it will shew on the equator, the hour after noon at London, when it is noon at Jamaica; or that London passes under the meridian about 5h. 4 min. before Jamaica arrives at it.

Problem XIX. *The summer solstice.*

221. Rectify the globe to the extremity of the divisions for the month of June, or to 23½ degrees north declination; then that part of the earth's surface, which is within the northern polar circle, will be all illuminated by the sun, and the inhabitants thereof will have continual day.

But all that space which is contained within the southern polar circle, will be at the same time in the shade, and have continual night.

222. In this position of the globe, we see how the diurnal arches of the parallels of latitude decrease, as they are more and more distant from the elevated pole.

223. If any place be brought under the strong brass meridian, and the horary index be set to that XII which is most elevated, and if that place be brought to the western side of the broad paper circle, the hour index will shew the time of sun rising; and when moved to the eastern edge, the index points to the time of sun-setting; the length of the day is obtained by the time shewn by the horary index, while the globe is turned from the west to the east side of the illuminated disc.

Thus it will be found that at London the sun rises about 15 minutes before IV in the morning, and sets about 15 minutes after VIII at night.

At the following places it will be nearly at the times expressed.

	⊙ Rising. h. m.	⊙ Setting. h. m.	Length of Day. h. m.	Twilight. h. m.
Cape Horn	8 44	3 16	6 32	2 35
Cape of Good Hope	7 09	4 51	9 42	1 43
Rio de Janeiro in Brazil, near the tropic of Capricorn	6 42	5 19	10 38	1 23
The island of St. Thomas at the equator.	6 0	6 0	12 0	1 20
Cape Lucas, the southernmost point of California, at the tropic of Cancer.	5 12	6 48	13 36	1 35

We also see, that at the time when the sun rises at London, it rises at the island of Sicily in the Mediterranean, and at the island of Madagascar.

And that at the time when the sun sets at London, it is setting at the island of Madeira, and at Cape Horn.

And when it is sun-setting at the island of Borneo in the East Indies, the sun is rising at Florida in America.

Problem XX. *Winter solstice.*

224. Rectify the globe to the extremity of the divisions for the month of December, or to 23½ degrees south declination.

At this season it will be apparent, that the whole space within the southern polar circle is in the sun's light, and enjoys continual day; whilst that of the northern polar circle is in the shade, and has continual night.

Then if the globe be turned as before, the horary index will shew, that at the several places before mentioned, their days will be respectively equal to what their nights were at the time of the summer solstice.

It will appear to be sun-setting at the time it was then sun-rising; and on the contrary, sun-rising at the time it then appeared to set.

THE TERRESTRIAL HORIZON,

225. As has been described Art. 117, is a small brass circle with one diameter that passes through its center; its circumference is divided into eight parts, which are marked with the initial letters of the mariner's compass, the four cardinal points of the horizon being distinguished from the rest; this may be slipped from pole to pole on the moveable meridian, and by this means be set to any place upon the globe.

When the center of it is set to any particular place, the situation of any other places is seen with respect to that place; that is, whether they be east, west, north, or south; thus it represents the sensible horizon.

It will also shew, why the sun appears at different altitudes and azimuths, although he is supposed to be always in the same place.

PROBLEM XXI. *The sun's altitude, as observed with a terrestrial or visible horizon.*

226. The altitude of the sun is greater or less, according as one of the parallel right lines or rays, coming from the sun to us, is farther from, or nearer to, our horizon.

Apply the terrestrial horizon to London, the sun being supposed in the zenith, or on the ceiling directly over the globe.

If then from London a line pass vertically upwards, the sun will be seen from London in that line.

At sun rising, when London is brought to the west edge of the broad paper circle, the supposed line will be parallel to the terrestrial horizon, and from London will be then seen in the horizon.

As the globe is gradually turned from the west towards the east, the horizon will recede from the line which passes perpendicularly upwards; for the line in which the sun was then seen, seems to glide farther and farther from the terrestrial horizon; that is, the sun's altitude increases as gradually as that line declines from the terrestrial horizon.

When the horizon, and the line which goes from London vertically upwards, are arrived at the strong brass meridian, the sun is then at his greatest or meridian altitude for that day; then the line and horizon are at the largest angle they can make that day with each other.

After which, the motion of the globe being continued, this angle between the terrestrial horizon and the line, which goes from London vertically upwards, continually decreases, until London arrives at the eastern edge of the broad paper circle; its horizon then becomes vertical again, and parallel to the line which goes vertically upwards, and will then appear in the horizon, and be seen to set.

Problem XXII. *The sun's meridian altitude at three different seasons.*

227. Rectify the globe to the time of winter solstice, Art. 224, and place the center of the visible horizon on London.

When London is at the graduated edge of the strong brass meridian, the line which goes vertically upwards, makes an angle of about 15 degrees; this is the sun's meridian altitude at that season to the inhabitants of London.

228. If the globe be rectified to the time of equinox, Art. 220, the horizon will be farther separated from the line which goes vertically upwards, and makes a greater angle therewith, it being about 38¼ degrees; this is the sun's meridian altitude at the time of equinox at London.

229. Again rectify the globe to the summer solstice, Art. 221, and you will find the visible horizon recede farther from the line which goes from London vertically upwards; and the angle it then makes with the horizon is about 62 degrees, which shews the sun's meridian altitude at the time of the summer solstice.

Hence flows the following arithmetical

Problem XXIII. *To find the sun's meridian altitude universally.*

230. Add the sun's declination to the elevation of the equator, if the latitude of the place and declination of the sun are both on the same side.

If on contrary sides, subtract the declination from the elevation of the equator, and you obtain the sun's meridian altitude.

	°	′
Thus, the elevation of the equator at London -	38	28
Sun's declination May 20th, - - - -	20	8
Their sum is the sun's meridian altitude for that day at London - - - - -	58	36
Again, to the elevation of the equator at London,	38	28
Add the sun's greatest declination at the time of the summer solstice, - - -	23	29
Their sum is the sun's greatest meridian altitude at London - - - - -	61	57

Whence also flows another method,

To find the sun's greatest and least altitude universally.

231. Add the sun's declination to, and subtract it from the elevation of the equator, their sum and difference will be the sun's meridian altitudes, when he hath the same declination either north or south.

	°	′
Thus, to and from the elevation of the equator	38	28
Add and subtract the sun's declination -	20	8
Their sum is the sun's meridian altitude in summer,	58	36
Their difference his meridian altitude in winter,	18	20

having the same declination one north, the other south.

PROBLEM XXIV. *The sun's azimuth compared with the visible horizon.*

232. Imagine the sun, as we have done before, to be painted on the ceiling directly over the globe, Art. 218, and a line going vertically upwards towards the sun from any place on the surface of the globe: If to that place you apply the visible horizon, that point of it which a vertical line is nearest to at any time, shews the sun's azimuth at that time: and we must also observe, that that point of the terrestrial or visible horizon, to which a vertical line is nearest, is always the most elevated point.

233. Rectify the globe to the position of a right sphere, Art. 214, and apply the visible horizon to London. When London is at the western edge of the broad paper circle, which situation represents the time when the sun appears to rise, the eastern point of the visible horizon being then most elevated, shews that the sun at his rising is due east.

Turn the globe till London comes to the eastern side of the paper circle, then the western point of the visible horizon will be most elevated, and shew that the sun sets due west.

If the globe be rectified into the position of an oblique sphere, Art. 215, and London be brought to the eastern or western side of the broad paper circle, the vertical line will depart more or less from the east and west points: in which cases the sun is said to have more or less amplitude either north or south as this departure tends to either of those two cardinal points.

As the globe is turned to any particular time of the day, we shall have the sun's azimuth upon that point of the visible horizon which is most elevated;

and this will be the point wherein a line going towards the sun is nearest to a vertical line; thus, if a line going towards the sun, be nearest the south-east point, the sun is then said to have 45 degrees azimuth eastward, that point being 45 degrees from the meridian.

234. In all positions of the globe in north latitude, when London is brought to the strong brass meridian, the most elevated point of the visible horizon will always be the south point of it, which shews that the sun, at all seasons of the year, will appear to the south of the terrestrial horizon in all places included in the northern temperate zone; but to the north of it at those places within the southern temperate zone.

235. THE ANCIENT DISTINCTION OF THE DIFFERENT PLACES ON THE EARTH, ACCORDING TO THE DIVERSITY OF THE SHADOWS OF UPRIGHT BODIES AT NOON.

PROBLEM XXV. *The ascii, or those who on a certain day project no shade at noon.*

236. Rectify the globe by Problem xix. Art. 221, to the time of the summer solstice, and apply the terrestrial horizon to any place situated on the tropic of Cancer, as Canton in China, and observe the sun's meridian altitude with it, by bringing its center under the strong brass meridian, Art. 226, it will then appear, that a line going vertically upwards, will be perpendicular to it, consequently the sun will be at that time directly over the heads of the inhabitants of Canton, and project no shadow; therefore they are ascii, their noon shadow being directly under them.

At all other times of the day, their shadow is projected, in the morning directly westward, and in the evening directly eastward.

The same thing will happen to all the inhabitants, who live between the tropic of Cancer and that of Capricorn, if the terrestrial horizon be gradually removed from parallel to parallel within these limits, and the globe rectified according to the day of the month as before directed; by bringing the sensible horizon to the strong brass meridian, to observe the sun's meridian altitude, we shall find him appear to be 90 degrees high, or vertical, at noon, to every place between the tropics; all the inhabitants being ascii twice a year, except those on the tropics themselves, who are ascii only once a year.

PROBLEM XXVI. *The inhabitants of all places between the tropics of Cancer and Capricorn, are not only ascii, but amphiscii, whose noon-shadows are projected sometimes towards the north, at other times towards the south.*

237. Place the sensible horizon on the equator, and rectify the globe to the time of the equinox, Art. 220, at which time the equatorial inhabitants are ascii at noon, having the sun full east of them all the morning, and full west all the afternoon.

The eastern point of the sensible horizon will be always uppermost, or most elevated, as the globe is moved from west to east, till it comes to the strong brass meridian; and after it has passed this, the western point will be most elevated.

The sensible horizon remaining on the equator, rectify the globe to the time of the summer solstice, Art. 221, and you will find the north point at noon will be most elevated; which plainly shews, that the inhabitants of the equator will see the sun full north at that season, and that their shade will be projected southwards.

238. If the globe be rectified to the winter solstice, Art. 224, the south point will be most elevated, and the inhabitants will see the sun on their south side, which will project their shadows northwards.

239. Heteroscii, are those who live between the tropics and polar circles, whose noon-shadows are projected one way only.

Those in north latitude have their noon-shadows projected northwards; the sun at that time being always in the south.

And those in south latitude have their noon-tide shadows projected southwards; the meridian sun always appearing to them in the north.

240. Periscii are those who live within the polar circles, the sun going continually round them, their shadow must necessarily go round them also.

If the sensible or terrestrial horizon be applied to any of these places, and the globe rectified according to the preceding directions, it will shew, that the sun appears to be more elevated at one time of the day than at another; and also, which way at all times the noon and other shadows are cast.

241. Antœci are two opposite nations, lying in or near the same meridian, one of them in north, the other in south latitude; they have both the same longitude, and equal latitude, but on opposite sides of the equator: they have opposite seasons of the year, but the same hours of the day.

242. Periœci are two nations situated on opposite

sides of the globe, in the same parallel of latitude, having the same seasons of the year, and opposite hours of the day.

Therefore their longitude must differ 180 degrees.

243. Antipodes are two nations diametrically opposite, which have opposite seasons as well as opposite hours.

A straight line passing from one to the other must consequently pass through the center, and therefore become a diameter of the globe.

Their longitude and latitude are both opposite.

These are exemplified by rectifying the globe into the position of a right sphere, Art. 220, and bringing the nations under consideration to the edge of the broad paper circle. Thus,

The inhabitants of the eastern parts of Chili are Antœci to those of New England; whose Periœci live in the northern parts of China, who are also antipodes to the inhabitants of Chili.

We shall now proceed to exemplify the former precepts in a few particular problems.

PROBLEM XXVII. *To find all those places on the globe over whose zenith the sun will pass on any given day.*

244. Rectify the terrestrial globe, Art. 219, by bringing the given day of the month, on the backside of the strong brass meridian, to coincide with the plane of the broad paper circle, and observe the elevation of the pole on the other side; and that degree counted from the equator on the strong brass meridian, towards the elevated pole, is the point

over which the sun is vertical. Now turning the globe, all those places which pass under this point, have the sun directly vertical on the given day.

Thus bring the 11th day of May, into the plane of the broad paper circle, and the said plane will cut 18 degrees for the elevation of the pole, which is equal to the sun's declination for that day; which counted on the strong brass meridian towards the elevated pole, is the point over which the sun will be vertical. Now turning the globe round, we shall find that Amalagan, one of the Ladrone islands, the northern part of Manilla, the middle of Siam, a great part of Africa, and St. Anthony one of the Cape Verd Isles, the southern side of the islands Porto-Rico and Domingo, and the northern part of the island of Jamaica, &c. have all of them the sun in their zenith on the 11th of May.

Hence when the sun's declination is equal to the latitude of any place in the torrid zone, the sun will be vertical to those inhabitants that day.

Hence also we derive the following

PROBLEM XXVIII. *To find the sun's declination, and thence the parallel of latitude corresponding therewith, upon the terrestrial globe.*

245. Find the sun's place upon the broad paper circle for any given day, Art. 98, and seek that place in the ecliptic line upon the globe; this will shew the parallel of the sun's declination among the dotted lines, which is also the corresponding parallel of latitude; therefore all those places through which this parallel passes, have the sun in their zenith at noon on the given day.

Problem XXIX. *To find those two days on which the sun will be vertical to any place between the tropics.*

246. That parallel of declination which passes through the given place, will cut the ecliptic line upon the globe in two points, which denote the sun's place, against which, on the broad paper circle, are the days and months required.

Problem XXX. *The day and hour at any place being given, to find where the sun is vertical at that time.*

247. Let the given place be London, and time the 11th day of May at 4 minutes past V in the afternoon.

Rectify the globe to the day of the month, Art. 219, and you have the sun's declination 18 degrees north; bring London to the meridian, and set the horary index to XII, turn the globe till the index points to the given hour on the equator, 4 minutes past V, then Port-Royal in Jamaica will be under the 18th degree of the strong brass meridian, which is the place where the sun is vertical at that instant.

Problem XXXI. *The time of the day at any one place being given, to find all those places in which the sun is then rising, setting on the meridian, and where he is vertical; likewise those places in which it is midnight, twilight, and darknight, at the same instant; as well as those places in which the* *twilight is beginning and ending; and also to find the sun's altitude at any hour in the illuminated, and his depression in the obscure, hemisphere.*

248. Rectify the globe to the day of the month, Art. 219, on the backside of the strong brass meridian, and the sun's declination for that day, which is equal to the elevation of the pole, is given upon the graduated side of the brass meridian, by its coincidence with the plane of the broad paper circle; bring the given place to the strong brass meridian, and set the horary index to XII, upon the equator, turn the globe from west to east, until the horary index points to the given time. Then

All those places, which lie in the plane of the western side of the broad paper circle see the sun rising, and at the same time those on the eastern side of it see him setting.

It is then noon to all the inhabitants of those places under the upper half of the graduated side of the strong brass meridian, whilst at the same time those under the lower half have midnight.

All those places, which are then between the upper surface of the broad paper circle, and the wire circle under it, are in the twilight; which begins to all those places on the western side that are immediately under the wire circle, to which it is the dawning of the day; its end is at all those places in the plane of the paper circle, on which the sun has just begun to rise.

The contrary happens on the eastern side; the twilight is just beginning to those places in which the sun is setting, and its end is at the place just under the wire circle.

And all those places which are under the twilight wire circle have dark night, unless the moon is favourable to them.

All places in the illuminated hemisphere have the sun's altitude equal to their distance from the edge of the enlightened disc, which is known by fixing the quadrant of altitude to the zenith, and laying its graduated edge over any particular place.

The sun's depression is obtained in the same manner by fixing the center of the quadrant at the nadir.

PROBLEM XXXII. *To find the time of the sun's rising and setting, the length of day and night, on any day in the year, in any place whose latitude lies between the polar circles, and also the length of the shortest day and night in any of those latitudes, and in what climate they are.*

249. Rectify the celestial globe to the latitude of the given place, Art. 189, bring the artificial sun to his place in the ecliptic for the given day of the month; and then bring its center under the strong brass meridian, and set the horary index to that XII which is most elevated.

Then bring the center of the artificial sun to the eastern part of the broad paper circle, which in this case represents the horizon, and the horary index shews the time of the sun-rising; turn the artificial sun to the western side, and the horary index will shew the time of the sun-setting.

Double the time of sun-rising is the length of the night, and the double of that of sun-setting is the length of the day.

Thus on the 5th day of June, the sun rises at 3 h. 40 min. and sets at 8 h. 20 min. by doubling each number it will appear, that the length of this day is 16 h. 40 min. and that of the night 7 h. 20 min.

The longest day at all places in north latitude, is when the sun is in the first point of Cancer. And,

The longest day to those in south latitude, is when the sun is in the first point of Capricorn.

Wherefore the globe being rectified as above, and the artificial sun placed to the first point of Cancer, and brought to the eastern edge of the broad paper circle, and the horary index being set to that XII which is most elevated, on turning the globe from east to west, until the artificial sun coincides with the western edge, the number of hours counted, which are passed over by the horary index, is the length of the longest day; their complement to twenty-four hours gives the length of the shortest night.

250. If twelve hours be subtracted from the length of the longest day, and the remaining hours doubled, you obtain the climate mentioned by ancient historians: and if you take half the climate, and add thereto twelve hours, you obtain the length of the longest day in that climate; this holds good for every climate between the polar circles.

A climate is a space upon the surface of the earth, contained between two parallels of latitude, so far distant from each other, that the longest day in one differs half an hour from the longest day in the other parallel.

The climates are reckoned from the equator to the polar circle, where the longest day is twenty-four hours; from the polar circle towards the pole the climates are said to increase by a whole natural day, till they come to a parallel under which the longest day is fifteen natural days, or half a month, from this the climates are reckoned by half months, or whole months, in the length of the artificial day, till they come to the pole itself, under which the day is six months long.

PROBLEM XXXIII. *To find all those places within the polar circles, on which the sun begins to shine, the time he shines constantly, when he begins to disappear, the length of his absence, as well as the first and last day of his appearance to those inhabitants; the day of the month, or latitude of the place being given.*

251. Bring the given day of the month on the backside of the strong brass meridian, to the plane of the broad paper circle, the sun is just then beginning to shine on all those places which are in that parallel, just touched by the edge of the broad paper circle; and will for several days seem to skim all around, and but a little above the horizon, just as it appears to us at its setting; but with this observable difference, that whereas our setting sun appears in one part of the horizon only, by them it is seen in every part thereof; from west to south, thence east to north, and so to the west again.

Or if the latitude was given, elevate the globe to that latitude, and on the backside of the strong brass meridian you obtain the day of the month, then all the other requisites are answered as above.

As the two concentric spaces which contain the days of the month on the back of the strong brass meridian, are graduated to shew the opposite days of the year, at 180 degrees distance; when the given day is brought to coincide with the broad paper circle, it shews when the sun begins to shine on that parallel, which is the first day of its appearance above the horizon of that parallel: and the plane of the said broad paper circle cuts the day of the month on the opposite concentric space, when the sun begins to disappear to those inhabitants; thus the length of the longest day is obtained, by reckoning the number of days between the two opposite days found as above; and their difference from 365 days gives the length of their longest night.

PROBLEM XXXIV. *To find the length of any day in the year, in any latitude.*

252. Elevate the celestial globe to the latitude, and set the center of the artificial sun to his place upon the ecliptic line on the globe for the given day, and bring its center to the strong brass meridian, placing the horary index to that XII which is most elevated; then turn the globe till the artificial sun cuts the eastern edge of the horizon, and the horary index will shew the time of sun-rising; turn it to the western side, and you obtain the hour of sun-setting.

The length of the day and night will be obtained, by doubling the time of sun-rising and setting, as before.

PROBLEM XXXV. *To find the length of the longest and shortest days in any latitude.*

253. Elevate the globe according to the latitude, Art. 189, and place the center of the artificial sun for the longest day upon the first point of Cancer, but for the shortest day on the first point of Capricorn, then proceed as in the last Problem.

But if the place hath south latitude, the sun is is in the first point of Capricorn on their longest day, and in the first point of Cancer on their shortest day.

Note. This Problem is only to be used in such latitudes as lie between the northern and southern polar circles.

PROBLEM XXXVI. *To find the latitude of a place, in which its longest day may be of any given length between twelve and twenty-four hours.*

254. Set the artificial sun to the first point of Cancer; bring its center to the strong brass meridian, and set the horary index to XII; turn the globe till it points to half the number of the given hours and minutes; then elevate or depress the pole, till the artificial sun coincides with the horizon, and that elevation of the pole is the latitude required.

PROBLEM XXXVII. *To find the distance between any two places.*

255. Lay the graduated edge of the quadrant of

altitude over both places, and the number of degrees between them is their distance, which is reduced to geographical miles, by reckoning 60 to a degree, or to English miles by reckoning 69½ to one degree.

If both places lie under the same meridian their difference of latitude is the distance required.

If they are in the same parallel of latitude, their difference of longitude is the distance sought.

Problem XXXVIII. *To find all those places which are at the same distance from a given place.*

256. Rectify the globe by Problem xii, Art. 189. and bring the given place to the strong brass meridian, over which screw the center upon which the quadrant of altitude turns; now move the quadrant round, and all those places that are cut by any one point on the quadrant are equally distant from the given place.

Problem XXXIX. *To shew at one view upon the terrestrial globe for any given place, the sun's meridian altitude, his amplitude, or point of the compass, on which he rises and sets every day in the year.*

257. Rectify the globe to the latitude of the given place, Art. 189, bring that place to the strong brass meridian, and set the horary index to XII, screw the quadrant of altitude to the zenith of the horizon, and bring it to the brass meridian, you will then at one view see the sun's meridian altitude on every degree of the sun's declination for the

whole year, cut by the graduated edge of the quadrant of altitude, on the dotted parallels; these dotted parallels at the same instant also cut the edge of the broad paper circle now representing the horizon, in the point of the compass or amplitude, on which the sun is seen to rise on the east, or to set on the west side of the horizon, for every degree of declination throughout the year.

If you trace any of those parallels to the ecliptic line, you have the sun's place when he is upon that declination, and thence the day and month upon the horizon.

Also, the knowledge of the sun's place in the ecliptic line, shews the sun's declination for that time amongst the dotted parallels.

PROBLEM XL. *To shew at one view upon the terrestrial globe the length of the days and nights at any particular place, for all times of the year.*

258. Rectify the globe to the latitude of the place, Art. 189, and the broad paper circle will represent the horizon: and the upper part of the dotted parallels of declination, which are here also parallels of latitude, will represent the diurnal arches.

Whence we may obtain the number of hours each of them contains, which is the solution of the Problem. To illustrate which,

Elevate the globe to the position of a right sphere, Art. 214, and you will, with one glance of the eye, see that all the dotted parallels of declination, as well as the equator itself, are cut by the horizon into two equal parts.

Therefore the inhabitants on the equinoctial line have their days and nights twelve hours long; that is, the sun is never more nor ever less than twelve hours above their horizon, during his apparent passage from the tropic of Cancer to the tropic of Capricorn, and thence to Cancer again.

All the fixed stars have the same apparent motion to the equatorial inhabitants; that is, they rise and set, continue above, and are depressed below, the horizon of any place upon the equator, exactly twelve hours.

Raise the north pole of the globe a few degrees of latitude at a time, and you will see the diurnal arches will increase in length, until the pole is elevated to 66½ degrees above the horizon: then the parallel of the sun's greatest declination will be as far from the equator as the place itself is from the pole; and this parallel is the tropic of Cancer, which will just touch the horizon in the north point.

And on the contrary, we may observe, that the southern parallels of declination continually shorten, as the northern ones lengthen, until they come to the tropic of Capricorn.

Rectify the globe to the latitude of London 51½ degrees north: when the sun is in the tropic of Cancer, the day is about 16½ hours; as he recedes from thence, the days shorten, as the length of the diurnal arches of the parallels shortens, until the sun comes to Capricorn, and then the days are at the shortest, being of the same length with the nights, when the sun was in Cancer, viz. about 7¼ hours.

Rectify the globe to the altitude of the northern polar circle, and you will find, when the sun is in Cancer, he touches the horizon on that day without setting, being completely twenty-four hours above the horizon: and when he is in Capricorn, he once appears in the horizon, but does not rise for the space of twenty-four hours; when he is upon any other parallel of declination, the days are longer or shorter, as that parallel is nearer to, or farther from, the equator.

Elevate the globe to the latitude of 80 degrees north, at which time let the sun's declination be 10 degrees north, he then apparently seems to turn round above the horizon without setting, and never sets from this point to Cancer, until in his return, after he has again passed this parallel of declination.

In the same manner, when his declination is 10 degrees south, he is just seen at noon in the horizon, and disappears from that time in his southerly motion, till his return to the same point.

Elevate the north pole to 90 degrees, or in the zenith, then the globe will be in the position of a parallel sphere, (Art. 210,) and the equinoctial line will coincide with the plane of the horizon: consequently all the northern parallels are above, and all the southern parallels below the horizon; therefore the polar inhabitants, if any there be, have but one day and one night throughout the year; their day, when the sun is in his northern; and their night, when he is in his southern, declination.

This method of rectifying the globe for north latitude holds good in south latitude also, by elevating the south pole.

PROBLEM XLI. *To find what constellation any remarkable star, seen in the firmament, belongs to.*

259. Bring the sun's place in the ecliptic for that day to the strong brass meridian, and set the horary index to that XII which is most elevated, the celestial globe being rectified to the latitude, turn the globe till it points to the present hour; and by the help of the mariner's compass, and attending to the variation, which at London is between 23 and 24 deg. from the north, westward, set the north pole of the globe towards the north pole of the heavens.

The star upon the globe, (if you conceive yourself in the center,) which directs towards that point in the heavens, in which the star you want to know is seen, is the star required.

At the same time, by comparing the stars in the heavens with those upon the globe, the other stars and their constellations may be easily known; whereby you will be enabled, any star-light night, to point out many of those stars called correspondents to various places on the earth.

PROBLEM XLII. *To find at what hour any known star passes the meridian on any day in the year.*

260. Rectify the globe to the latitude, (Art. 189,) and set the artificial sun to his place in the ecliptic: bring its center under the strong brass meridian, and set the horary index to XII; then turn the globe till the star comes to the meridian; and the

horary index will point upon the equator to the hour on which that star will be upon the south part of the meridian.

If you turn the globe on till the center of the artificial sun is under that graduated side of the brass meridian, which is below the elevated pole, all those stars, which are then cut by that side of the meridian above the said pole, will pass the meridian at midnight.

PROBLEM XLIII. *To find on what day of the year any star passes the meridian at any proposed hour of the night.*

261. Bring the star to the strong brass meridian, and set the horary index to the proposed hour; then turn the globe till the index points to XII, and that degree on the ecliptic, which is cut by the meridian, is the sun's place, against which, in the kalendar upon the broad paper circle, is the day of the month.

PROBLEM XLIV. *To trace the circles of the sphere in the starry firmament.*

262. We shall solve this problem for the time of the autumnal equinox; because that intersection of the equator and ecliptic will be directly under the depressed part of the meridian about midnight; and then the opposite intersection will be elevated above the horizon: and also because our first meridian upon the terrestrial globe passing through London, and the first point of Aries, when both globes are rectified to the latitude of London, and

to the sun's place by Problem xii. Art. 189, 192, and the first point of Aries is brought under the graduated side of each of their meridians, we shall have the corresponding face of the heavens and the earth represented, as they are with respect to each other at that time, and the principal circles of each sphere will correspond with each other.

The horizon is then distinguished, if we begin from the north, and count westward, by the following constellations: the hounds and waist of Bootes, the northern crown, the head of Hercules, the shoulders of Serpentarius, and Sobieski's shield; it passes a little below the feet of Antinous, and through those of Capricorn, through the Sculptor's frame, Eridanus, the star Rigell in Orion's foot, the head of Monoceros, the Crab, the head of the little Lion, and lower part of the great Bear.

The meridian is then represented by the equinoctial colure, which passes through the star marked δ in the tail of the little bear, under the north pole, the pole star, one of the stars in the back of Cassiopea's chair marked β, the head of Andromeda, the bright star in the wing of Pegasus marked γ, and the extremity of the tail of the whale.

That part of the equator, which is then above the horizon, is distinguished on the western side by the northern part of Sobieski's shield, the shoulder of Antinous, the head and vessel of Aquarius, the belly of the western fish in Pisces; it passes through the head of the whale, and a bright star marked δ in the corner of his mouth, and thence through the star marked δ in the belt of

Orion, at that time near the eastern side of the horizon.

That half of the ecliptic which is then above the horizon, if we begin from the western side, presents to our view Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, and a part of the constellation Cancer.

The solstitial colure, from the western side, passes through Cerberus, and the hand of Hercules, thence by the western side of the constellation Lyra, and through the dragon's head and body, through the pole point under the polar star, to the east of Auriga, through the star marked η in the foot of Castor, and through the hand and elbow of Orion.

The northern polar circle, from that part of the meridian under the elevated pole, advancing towards the west, passes through the shoulder of the great bear, thence a little to the north of the star marked α in the dragon's tail, the great knot of the dragon, the middle of the body of Cepheus, the northern part of Cassiopea, and base of her throne, through Camelopardalus, and the head of the great bear.

The tropic of Cancer, from the western edge of the horizon, passes under the arm of Hercules, under the Vulture, through the goose and fox, which is under the beak and wing of the swan, under the star called Sheat marked β in Pegasus, under the head of Andromeda, and through the star marked φ in the fish of the constellation Pisces, above the bright star in the head of the ram marked α, through the Pleiades, between the horns of the bull, and through a group of stars at the foot of Castor, thence above a star marked δ, between Castor and Pollux, and so through a part of the constellation Cancer, where it disappears by passing under the eastern part of the horizon.

The tropic of Capricorn, from the western side of the horizon, passes through the belly, and under the tail of Capricorn, thence under Aquarius, through a star in Eridanus marked c, thence under the belly of the whale, through the base of the chemical furnace, whence it goes under the hare at the feet of Orion, being there depressed under the horizon.

The southern polar circle is invisible to the inhabitants of London, by being under our horizon.

TO FIND THE TIME OF THE SUN'S ENTRY INTO THE FIRST POINT OF LIBRA OR ARIES; AND THENCE THAT POINT IN THE EQUATOR TO WHICH THE SUN IS VERTICAL AT EITHER OF THOSE TIMES.

263. This requires the knowledge of a meridian that shall pass through that point in the equator, to which the sun is vertical at the times of equinox; but as this point is variable, a fixed meridian must be first obtained.

In Anno Domini 1753, the late Rev. Dr. Bradley observed the sun to enter Libra September 22d. 10h. 24 min. afternoon, new stile, at the Royal Observatory at Greenwich.

As the earth's diurnal motion is from west to east, it causes all places to the east of any other place to pass first under the sun; therefore when the meridian of Greenwich passed under the sun that day, he was not then arrived at the intersecting point of the earth's equator and celestial ecliptic, but wanted 10h. 24 min. which is equal to 156 degrees.

Whence the fixed or first meridian sought is thus obtained, and lies 10h. 24 min. in time, or 156 equatorial degrees west of the Royal Observatory at Greenwich.

This meridian is marked by a dotted line on our new terrestrial globe; it passes through the Great Pacific sea, and crosses one of the Isles of St. Bernard, and the Isles des Mouches.

The next thing to be considered is the nearest mean length of a tropical year, which is a determinate space or interval of time between the sun's apparent passage from one point of the ecliptic, until he returns to the same point again, or from one equinox to the same again, be it either vernal or autumnal.

We take for our radix the autumnal equinox, Anno 706 of the Julian period, which we call Anno Mundi 0, and compute from Thursday, Oct. 25th, 0h. 0 min. or noon, the sun being then supposed to be in the first point of Libra on the meridian before mentioned, and vertical to that point of the equator, which lies 156 degrees west of Greenwich.

And also in the meridian of Greenwich, Oct. 25th, 10h. 24 min. upon the 298th day from the calends of January.

The tropical year thus reckoned exceeds the Egyptian year 5h. 49 min. and is but 11 minutes short of the Julian year; so much being annually allowed for the retrocession of the equinox, consequently the mean length of a tropical year is 365 d. 5 h. 49 min.

We are induced to measure time by this quantity, because astronomers unanimously agree, that the earth passes through all the signs of the ecliptic, so as to complete the circle in 365 d. 5 h. 49 min.

See the respective tables of Rudolphus, Tycho Brahe, Cassini, Sir Jonas More, Mr. Flamsted, Dr. Halley, Mr. Meyer, and Mr. Maskelyne; whereby it will appear that

	s	°	′	″
The sun's mean motion in 365 days is	11	29	45	40
in 6 hours			14	47
	0	0	0	27
Subtract, for retrocession, the sun's mean motion in 11 minutes of time,				27
	0	0	0	0

	d.	h.	m.
The quantity of one Julian year, is	365	6	0
From which subtract the retrocession			11
Therefore the remainder	365	5	49

completes the circle, and not one second of time more or less can be produced from any tables extant.

And the difference between calculating downwards from the epoch A. J. P. 706, and calculating backwards in the modern practice, from the various epochs in the most celebrated tables, is, that in those last epochs, the 11 minutes of retrocession have not been considered.

	d.	h.	m.
From the vernal to the autumnal equinox	186	11	51
From the autumnal to the vernal equinox	178	17	58
	365	5	49

The equinoxes regularly fall every year 5 h. 49 min. later in the day, than in the preceding year, and at the end of every annual motion of the earth, the equinoctial intersection changes its meridian westward of that in which it fell the year before, just 87 deg. 15 min.

PRECEPTS FOR THE USE OF THE TABLES OF RETROCESSION AND AUTUMNAL EQUINOXES.

264. First, Find the number of years from the radix: if the given year is before the Christian Æra, subtract it from 4008; the remainder is the year from the radix.

Secondly, If any year since the Christian Æra be given, add it to 4007, their sum is the year from the radix.

Thirdly, Collect the days, hours, and minutes of retrocession and autumnal equinoxes from the table, according to the number of years from the radix, in thousands, hundreds, tens, and units; add these into two sums, the first will be the retrocession, the second the time of the equinox in that meridian, which lies 156 degrees west of

Greenwich Observatory; to which add 10h. 24m. and you obtain the time at Greenwich.

This method will serve for any other meridian also, if you add its difference in time from the fixed meridian.

Solar tropical years thus reckoned begin and end at the autumnal equinox, and all Julian years begin and end at the kalends of January.*

In comparing solar tropical years with Julian years, by which we still compute time, observe, that the last nine months of any solar tropical year answer to the first nine months of that Julian year with which it is compared; and that the first three months of the next succeeding tropical year answer to the three last months of that same Julian year with which it is compared.

The 298th day from the kalends of January, which was Thursday in the 706th year of the Julian period, the sun entered Libra at noon; at which instant it was 10h. 24min. past noon at Greenwich.

In all calculations of autumnal equinoxes, we take the same 298th day, or October 25th in the radical year 0, for our epoch.

And to gain the day of the month in which the equinox must happen since the radix,

Add the number of days, hours, and minutes in the retrocession, to the days, hours, and minutes of the equinox in the fixed meridian, and you obtain the Julian days and hours from the radix.

* The kalends of January begin from the noon of the preceding day; that is, from the noon of the day before the first of January.

Add the epoch 298 to the days of the tropical reduction, and from their sum subtract the entire days of the Julian reduction, the remainder is the number of days from the kalends of January old stile; add thereto eleven days, and you obtain the number of days from the said kalends of January new stile; from which if you deduct the nearest less number in the table of months (which numbers express the last days of each month) the residue is the day of the succeeding month.

But when the sum of the Julian reduction contains eighteen hours above entire days, it is a bissextile year; then one day more must be added to the entire Julian days before the subtraction is made.

When there are no hours in the Julian reduction, that is the first year after a bissextile; if six hours, the second; if twelve hours, the third; and when eighteen hours above entire days, it is the bissextile year.

And when the last result exceeds 12 hours, add 1 to the days, and subtract 12 from the hours, and you change the time from astronomical to the civil reckoning.

To gain the time of the equinox on any other meridian, add the difference of meridians to the time found in the first meridian. Thus for London or Greenwich we add 10 h. 24 min.; for Paris, 10 h. 33 min. 20 sec.; for Alexandria in Egypt, 12 h. 25 min. &c.

TO GAIN THE WEEK DAY.

265. Divide the days of the tropical reduction by

7; if 0 remains, it is Thursday; if 1, Friday; 2, Saturday; and 3, Sunday; and so on to 6, which is Wednesday, as in the table of week-days.

TO OBTAIN THE TIME OF THE VERNAL EQUINOX.

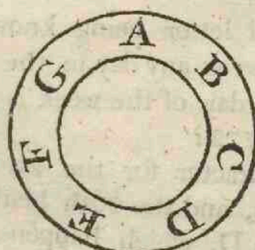
266. First find the autumnal equinox for the same year in which the vernal equinox is required; and from it subtract 186 deg. 11 h. 51 min. which is the distance in time from Aries to Libra; their difference will be the time of the vernal equinox required.

The day of the month, and week-day found as above, we obtain the literal character for that day as follows:

In the table of months stand the literal characters, that are placed against the first day of each month in any common almanack.

And whatever letter stands against the first day of any month, the 8th, 15th, 22d, and 29th days of that month, are all characterised with the same.

A circle of the seven literal, or week-day characters.



THE DAY OF THE MONTH AND WEEK-DAY GIVEN, TO FIND ITS LITERAL CHARACTER AND DOMINICAL LETTER FOR THAT YEAR.

267. A. D. 1772, the autumnal equinox will happen at Greenwich, September 22d, 0 h. 55 min. on a Tuesday.

Quere, The literal character for that day and dominical letters for that year, it being bissextile?

The literal character for the first of September, is F; so is the 22d, and Tuesday in the present question. Look on the circle of week-day characters, call F Tuesday, G Wednesday, A Thursday, and so on to Sunday which falls upon D, the last of the two dominical letters for that year, serving from the intercalary day to the year's end.

The first dominical letter for leap-years is the next in the circle, and serves for January and February, which in this example is E.

Therefore the two dominical letters for the bissextile year 1772 are E D new stile.

In any common year, the letter first found serves for the whole year.

The dominical letter being known, to find on what day of the week any day in the year falls.

Quere, What day of the week is the 20th day of March, A. D. 1772?

The literal character for the 1st of March is D, so is the fifteenth, and the 20th being 5 days more, if we count from D, which happens to be the dominical letter, to E Monday the 16th, we shall find

B is Friday, the 20th day of March, A. D. 1772, new stile.

If the dominical letters were required for old stile, in these examples the first would be the 11th of September 1772, whose literal character is thus found: F the 1st day of September, and also the 8th, G the 9th, A the 10th, and B the 11th, and by the following calculus Tuesday, therefore A C are the dominical letters old stile, A. D. 1772.

268. Required the autumnal equinox at Alexandria in Egypt, in the 146th year before the Christian Æra.

4008
— 146

A. M. 3862 or years from the radix, October 25, A. J. P. 706.

	Retrocession.			Tropical reduction.		
years à radix.	d.	h.	min.	days à radix.	h.	min.
3000	22	22	0	1095727	2	0
800	6	2	40	292193	21	20
60	0	11	0	21914	13	0
2	0	0	22	730	11	38
	29	12	2	7)1410565	23	58

weeks 201509+2 Saturday.

		d.	h.	min.
Tropical day 565	tropical time	1410565	23	58
epoch + 298	retrocession +	29	12	2
863	Julian reduction	1410595	12	0
Julian days—595		the third year after bissextile.		
268				
for August—243				
♎ Sept. 25				

	d.	h.	min.	
à kal. Jan.	268	23	58	fixed meridian.
meridian dist. +		12	25	
the sun in the first point of Libra, Sept. 26,	269	12	23	at Alexandria.

On a Sunday, dominical letter B, in the 147th year before the Christian Æra.

269. To find the time of the vernal equinox in the same year, and at the same place.

	d.	h.	min.
From the autumnal equinox, Sept. 26, à kal. Jan.	269	12	23
subtract the distance in time between ♈ and ♎	186	11	51
	83	11	32
for February	59		
the sun in the 1st point of Aries at Alexandria before Christ 146 years, March	24	0	32

270. To find the time of the autumnal equinox at Greenwich, A. D. 1768.

4007
+1768

A. M. 5775 or years from the radix

	Retrocession.			Tropical reduction.		
years à radix.	d.	h.	min.	days à radix.	h.	min.
5000	38	4	40	1826211	19	20
700	5	8	20	255669	15	40
70	0	12	50	25566	23	10
5	0	0	55	1826	5	5
	44	2	45	7)2109274	15	15

weeks 301324+6 Wednesday.

Tropical days 274	tropical time	2109274	15	15	
epoch + 298	retrocession +	44	2	45	
572		2109318	18	0	
Jul. days + 1—319 because of the 18 h.	bissextile year.				
253 à kal. Jan. old style					
for new style + 11 days					
264 à kal. Jan. new style					
for August — 243					
☉ in ♎ Sept. 21		d.	h.	min.	
	in the fixed meridian à kal. Jan.	264	15	15	
	meridian dist. +	0	10	24	
the sun in the 1st point of Libra at Greenwich, Sept. 22,		265	1	39	

271. To find the time of the vernal equinox, A. D. 1768.

	d.	h.	min.
From the autumnal equinox, Sept. 22,	265	1	39
subtract dist. ♈ à ♎	186	11	51
	78	13	48
for Feb.	59	0	0
the sun in Aries at Greenwich, A.D. 1768, Mar.	19	13	48

272. Having found the autumnal and vernal equinoxes for the bissextile year, A. D. 1768, we obtain them for the three following years by continually adding thereto 5 h. 49 min. Thus

☉ in ♈	d.	h.	min.	☉ in ♎	d.	h.	min.
1768, March 19,	78	13	48	1768, Sept. 22,	265	1	39
	+	5	49		+	5	49
1769, March 19,	78	19	37	1769, Sept. 22,	265	7	28
	+	5	49		+	5	49
1770, March 20,	79	1	26	1770, Sept. 22,	265	13	17
	+	5	49		+	5	49
1771, March 20,	79	7	15	1771, Sept. 22,	265	19	6

273. Required the time of the autumnal equinox at Greenwich, A. D. 1772.

4007
1772

A. D. 5779 or years from the radix.

Retrocession.				Tropical reduction.		
years à radix.	d.	h.	min.	days à radix	h.	min.
5000	38	4	40	1826211	19	20
700	5	8	20	255669	15	40
70	0	12	50	25566	23	10
9	0	1	39	3287	4	21
	44	3	29	7)2110735	14	31
				weeks 301533+4 Monday.		

Tropical days	735	to the tropical time	2110735	14	31
epoch +	298	retrocession +	44	3	29
	1033		2110779	18	0
Jul. days+1—	786 because of the 18 h.		bissextile year.		
	253 à kal. Jan. old stile				
for new stile +	11 days				
	264 à kal. Jan. new stile				
for August —	243				

	d.	h.	min.
☉ in Libra Sept. 21 in the fixed meridian à kal. Jan.	264	14	31
meridian dist. +	0	10	24
the sun in the first point of Libra at Greenwich, Sept. 22,	265	0	55

On a Tuesday: Dominical Letters E. D.

274. To obtain the vernal equinox, A. D. 1772.

	d.	h.	min.
From the autumnal equinox, Sept. 22, à kal. Jan.	265	0	55
dist. from Aries to Libra	186	11	51
	78	13	4
for February	59		
the sun in the 1st point of Aries at Greenw. Mar.	19	13	4

We find the two equinoxes in the three next succeeding common years, as in the preceding example, by the continual addition of 5 hours, 49 minutes.

By this method of calculation, we avoid any mistake that might happen with respect to the intercalary day; because we find the autumnal equinox first, and thence the vernal equinox, which always falls after the intercalary day, and also because tropical time has no bissextile years.

TO REDUCE HOURS, MINUTES, AND SECONDS OF TIME, INTO DEGREES, MINUTES, AND SECONDS OF THE EQUATOR.

275. Divide the seconds of time by 4, the quotient is minutes, and remainder so many times 15 seconds.

Divide the minutes by 4, the quotient is degrees, and remainder so many times 15 minutes.

Multiply the hours by 15, the product is degrees.

EXAMPLE.

Reduce 11 h. 35 min. 27. sec. of time into degrees, minutes, &c. of the equator.

sec.	min.	h.		deg.	min.	sec.
4)27	4)35	11		165	0	0
—	—	15		8	45	0
6′ 45″	8° 45′	——		0	6	45
		165°				
			answer	173	51	45

TO REDUCE DEGREES, MINUTES, AND SECONDS OF THE EQUATOR, INTO HOURS, MINUTES, AND SECONDS OF TIME.

276. Divide seconds by 15, the quotient is seconds, and remainder so many times 4 thirds.

Divide minutes by 15, the quotient is minutes, and remainder so many times 4 seconds.

Divide the degrees by 15, the quotient is hours, and remainder so many times 4 minutes.

EXAMPLE.

Reduce 173 deg. 51 min. 45 sec. of the equator, into hours, minutes, and seconds of time.

sec.	min.	deg. h.	h. min. sec.
15)45(3″	15)51(3′	15(173(11	11 32 0
45	45	15	0 3 24
—	—	—	0 0 3
0	6=24″	23	———
		15	11 35 27 answ.
		—	
		8=32′	

We are now prepared to solve the latter part of the last problem, which is as follows.

PROBLEM XLV. *To find all those places in which it is noon at the time of an equinox, as well as that point upon the equator, to which the sun is vertical at that time.*

277. Having found the time of an equinox by the preceding, or any other method of calculation,

as in the first example, we find the sun entered the first point of Aries, at Alexandria in Egypt, March 24th, 0 h. 32 min.

The 32 minutes of time reduced to the equator, are equal to 8 degrees.

Therefore bring Alexandria under the graduated side of the strong brass meridian, and set the horary index to XII upon the equator; turn the globe from west to east until 32 minutes of time, or 8 degrees of the equator, have passed under the horary index, where stop the globe; then all those places under the said graduated side of the strong brass meridian will have noon, and that degree of the equator, which is then under the meridian, is the point to which the sun was at that instant vertical, and is the intersecting point of the equator and ecliptic, or that terrestrial meridian which governs the passage of the first point of Aries for that year.

THE VERNAL EQUINOX, A. D. 1772, WILL FALL ON THE 19TH DAY OF MARCH, AT 13 H. 4 MIN. WHICH REDUCED TO THE DEGREES AND MINUTES OF THE EQUATOR, IS EQUAL TO 196 DEGREES.

278. Bring London to the strong brass meridian, and set the horary index to XII, (in this case the graduated side is the horary index,) turn the globe from west to east until 13 h. 4 min of time, or 196 degrees of the equator, have passed under the horary index, where stop the globe; the 196th degree of the equator will now be found under the graduated side of the brass meridian, and is that point on which

the sun will be vertical at noon; at which instant it will be 13 h. 4 min. past noon at London or Greenwich.

The meridian passing through this point, will be seen to pass a little eastward of Kamkatska through the Pacific Sea across the Island Dicerta, thence east of the isle Taumago, and through the western part of New Zealand; all which places will have noon at the instant of that vernal equinox.

THE AUTUMNAL EQUINOX, A. D. 1772, WILL HAPPEN SEPTEMBER 22, 0 H. 55 MIN. AT LONDON, THE 55 MIN. BEING EQUAL TO 13 DEG. 45 MIN. OF THE EQUATOR.

279. Bring London to the graduated side of the strong brass meridian, and set the horary index to XII, turn the globe from west to east, until 55 minutes of time, or 13 deg. 45 min. of the equator have passed under the horary index, where stop the globe; here, as in the last example, the 13th degree and 45th minute is that point upon the equator to which the sun is vertical, and the meridian passing through this point, lies under the graduated side of the strong brass meridian; which passes over the middle of Greenland, and through the Atlantic Ocean to the east of Teneriffe, a little to the west of Ascension Island, and thence through the Ethiopic Ocean, at which places it will be noon at the time of this autumnal equinox.

Here it will be proper to give the reader a short account—

OF THE NATURAL AGREEMENT BETWEEN THE CELESTIAL AND TERRESTRIAL SPHERES; OR, HOW TO GAIN A PERFECT IDEA OF THE SITUATION AND DISTANCE OF ALL PLACES UPON THE EARTH, BY THE SUN AND STARS.

280. That part of the firmament which is in the zenith of London is perpendicular to half the globe of the earth; which half comprehends almost all the habitable land of Europe, Asia, Africa, and America, with their coasts, capes, land, and seas; since under the other celestial hemisphere, which we do not see at the same time, there are only very inconsiderable lands and isles.

The inhabitants of Great Britain and Ireland nearly see the same half of the firmament adorned with stars and planets, which at all times supply the place of an immense map of the world; and shew our terrestrial hemisphere by the stars, conveying the correspondent marks of the two continents to our sight and mind.

The sun, by his apparent daily motion, seems to describe a kind of spiral, in passing from one tropic to the other and back again, continually changing his declination, and every day describing a different parallel, Art. 171.

Forty-seven of these diurnal parallels are drawn on our new terrestrial globe, Art. 177, 178, between the tropics of Cancer and Capricorn, representing the parallels for every degree of the sun's declination.

Before the reader proceeds, he is desired, in order to be perfectly acquainted with the cause of the daily change in the sun's declination, to go back to Art. 185, and read from thence to the 189th Art.

Which being done, it will be easy to conceive, that the sun being in any one of these parallels, must necessarily cast his perpendicular rays that day upon the heads of the inhabitants of those places through which that parallel of declination passes.

Note. Although these 47 parallels are here called parallels of declination, they are also parallels of latitude upon the terrestrial globe.

From these principles we obtain the situation of those places, to which the sun is vertical every day in the year; we also find the time of that day at the place of any observer, from whence looking at the sun, we may pronounce him to be over the heads of the inhabitants of divers cities and states, during the several hours of that day, and so on for every day in the year.

The sun being perpendicularly over any one of these distant cities or principalities, at the time of our observation, if a plumb-line be held up between the observer and the sun, so as to pass through or before the sun's center, it will cut the visible horizon in a point, that will fix the bearing or passage in a right line from the observer to that place, upon which the sun is then vertical.

A point thus noted upon the visible horizon may be seen at all times, and represent the same bearing, independent of the sun and stars, and that in such a conspicuous manner as to render this knowledge always entertaining, useful, and interesting.

The stars at night perform the same more copiously, by pointing out to our senses the distance of many remote provinces, at one and the same instant of time, from our own zenith.

Hence we are in possession of a most extensive field, wherein we may correct and improve our astronomical and geographical knowledge.

EXAMPLES OF SOLAR CORRESPONDENTS.

PROBLEM XLVI. *To find the solar correspondence to a fixed point upon the earth, when the sun is seen by an observer situated upon any other point of its surface.*

EXAMPLE I.

281. Let the observer be in London (or in any of the country places within thirty miles of it) upon the 10th day of March, at 10 minutes past XI o'clock in the morning.

QUERE, The place upon which the sun will be vertical at that time?

Rectify the globe, by bringing the 10th of March, engraved on the back of the strong brass meridian, to the plane of the broad paper circle; find the sun's place, against the day of the month in the kalendar, which will be about 20 deg. 10 min. in Pisces; seek these degrees and minutes in the sign Pisces upon the ecliptic line on the globe, and you will find it fall upon the fourth parallel of south declination: to all the inhabitants on this parallel, the sun will be vertical that day. Now bring 11 h. 10 min. on the equator to the graduated side of the strong brass meridian, and you will find it cut the fourth southern parallel upon the city of Loango, on the western coast of Africa.

Therefore if you look at the sun 10 minutes past XI in the morning at London, you will then see him at the instant he is directly over the heads of the inhabitants of the city of Loango in Africa; at the same time, your ideas are made sensible of the comparative distance, which you see in the firmament between the zenith of London, under which you stand, and the sun, which is then in the zenith of Loango; also if at the time of your observation, you cause a plumb-line to be held up between you and the center of the sun, and cast your eye down towards the most distant part of your sensible horizon, the plumb-line will cut a point thereon, which, if remembered, will always shew you the true bearing or point of the compass, in a direct line from your situation, to that of Loango.

This distance and bearing may be nearly found by the globe thus:

Elevate the globe to the latitude of London, that the broad paper circle may represent your horizon; screw the nut of the quadrant of altitude in the zenith, that is, upon 51 deg. 32 min. counted from the equator towards the elevated pole, bring London under that point, and lay the graduated edge of the quadrant upon Loango, which will cut the bearing 15 degrees, reckoned from the south towards the east, or between the points S. S. E. and S. by E.; now separate the quadrant from the globe, and lay its graduated edge upon Loango and London, so that the beginning of the graduation may lie upon one of the places, then the other will cut 56 degrees, which is equal to 3360 geographical miles, or 3892 English miles, the distance between London and Loango.

To elucidate this example, we shall trace the sun's verticity over that part of this day's parallel of declination, which is included between the rising and setting sun at London for that day.

Imagine, as we have before supposed, an image of the sun to be painted upon the ceiling of the room, directly over the terrestrial globe.

Let the globe be rectified to the 10th of March, place the center of the artificial horizon upon London, and bring it into a coincidence with the west side of the plane of the broad paper circle, now representing the edge of the earth's illuminated disc; we shall then have the position of the earth with respect to the sun for that day; when the inhabitants of London will be leaving the twilight, and passing into the first point of day, or sun-rising, at about 18 minutes past VI in the morning, cut by the graduated side of the strong brass meridian on the hour line under the equator; at this time, the meridian will likewise cross the fourth parallel of south declination, in the Indian ocean, between the island of Sumatra and the Maldive Isles; if we look upon the sun that morning at the instant of his rising, we shall see that his distance from our zenith will then be 90 degrees, he being in our horizon, which is equal to 5400 geographical or 6155 English miles, the distance from London to that part of the Indian Sea ; turn the globe from west to east, until 8 h. 12 min. are under the horary index, which in this case is the strong brass meridian, and it will cut the isle Macarenhas, to which the sun will then be perpendicular; at ¼ past IX he will be perpendicular to the coast of Zanguebar, his central ray passing between Monibacca and Pemba; thence it passes over the kingdoms of Monomugi, Macoco, Congo, &c. until he is perpendicular to the city of Loango, upon the western coast of Africa, at 11 h. 10 min. the same morning; immediately after which, his perpendicular rays are absorbed in the Ethiopic Ocean, over which he is 3 h. 22 min. in passing to Fort St. Lucar, on the eastern coast of America, at 32 minutes past II in the afternoon; thence he proceeds to send forth his perpendicular rays over the heads of the inhabitants of Brazil, across the vast country of the Amazons and Peru, in the decline of our evening, until his arrival over Cape Blanco on the western side of South America, a little before he sets to the inhabitants of London, which is about 40 minutes past V o'clock.

Example II.

282. Every rectification being observed as in the first example; Q. What is the place upon which the sun is a correspondent at 48 minutes past VI in the evening of the 18th of May, the sun's place being about 17 deg. 40 min. in Taurus, or nearly vertical to the 17th parallel of north declination on that day? Turn the globe from west to east, until London has passed the strong brass meridian, and stop when its graduated side is directly over 6 h. 48 min. afternoon, and it will cut the 17th

parallel of north declination, the city of Acapulco on the western coast of Mexico, over which the sun will then be vertical.

Example III.

283. Let the observer be at Cape Clear on the western coast of Ireland, on the 16th day of July, at 54 minutes past VIII in the morning.

Quere, The place upon which the sun will then be vertical?

The sun's place being in the 24th degree of Cancer, which on the globe falls upon the 21st parallel of north declination,

Bring Cape Clear to the graduated side of the strong brass meridian, and set the horary index to XII, turn the globe till 8 h. 54 min. amongst the morning hours are under the horary index, and you will find the graduated side of the strong brass meridian to cut the 21st parallel of north declination upon Farrat in Nubia, on the western coast of the Red Sea.

Example IV.

284. Let the observer be at Rome on the 20th day of November, at 37 minutes past X in the morning.

Quere, The place upon which the sun will be vertical at that time?

The sun being about 28½ degrees in Scorpio, which falls to the southward of the 20th parallel of south declination,

Bring Rome to the graduated side of the strong brass meridian, and set the horary index to XII, turn the globe to have 10 h. 37 min. under the horary index, and the said graduated side will then cut, under the 20th parallel of south declination, the city of Sofalo in the kingdom of Quiteri, to the south of Monomotapa, on the eastern coast of Africa.

We apprehend these four examples are sufficient to give the reader a clear idea of the solar correspondents to all places within the torrid zone, and to enable him to discover some thousands more.

Although we can have but one solar correspondent at the same time, yet, as in the first example, we can trace him through his diurnal parallel for every hour and minute of the day, and so also upon every day in the year.

Nothing can be easier or more intelligible than this method of improving the mind, by representing to the eyes the distance from our own zenith to that of every spot of land and sea within the tropics; when at every single observation we have it also in our power to note the bearing of each of these places upon our visible horizon, which may be referred to at all times, when the sun is not in that parallel.

Let us now change the scene, and proceed from the consideration of the sun, to that of the stars; which will present to our view a copious field of geographical knowledge; many of these may be seen at one and the same instant of time, when they are in the zenith of so many different places upon the earth, and then immediately afterwards remove from that designation, to give place for a great number of others.

OF THE CELESTIAL CORRESPONDENTS.

285. The knowledge of the celestial correspondents discovers a new system of astronomical geography. The perfect agreement between the celestial and terrestrial spheres constitutes this system; which may with very little trouble be understood, by making the study of one a guide to the knowledge of the other; the object of this correspondence is the continual variation between the parts of the celestial and terrestrial spheres.

Geography alone being easier than astronomy, has generally a particular place in the education of young students, who seldom leave their juvenile studies without gaining some idea of the four quarters of the world, a slight notion of the situation of places with respect to each other, and a sketch of the principal empires; but generally without any application to the terrestrial, and scarce ever a comparison of that with the celestial globe; and without feeling a lively curiosity to become acquainted with these necessary and improving branches of science.

To facilitate the study of geography, it has always been necessary to lay maps and charts before a pupil, which are generally separate plans of different countries. But what idea do these afford of the vast extent of the earth, of its spherical form, or of the proportionable distances, real bearings, &c. of the empires, kingdoms, and states on the habitable part of our terrestrial globe?

How much more intelligible and just are the proportionable distances of the fixed stars, when compared with the natural distances of the several places upon the earth, over which they dart their perpendicular rays; thereby constituting this new system of astronomical geography, by ocular demonstration? They are faithful testimonies of the vast extent of the universe, and they declare the distance, bearing, and situation of all places upon the earth.

By these means, together with the assistance of maps and charts, such a copious and clear idea of geography will be attained, and its natural principles so firmly established, as never to be erased.

The consequences to be drawn from these principles are entirely in favour of the harmony between the celestial and terrestrial spheres.

OF THE PASSAGE OR TRANSIT OF THE FIRST POINT OF ARIES OVER THE MERIDIAN.

286. This point determines the apparent daily motion of the heavens, and fixes the continual difference in the course of the sun and stars.

The knowledge of that particular point on the terrestrial equator, where its intersection with the celestial ecliptic happens to fall at the time of a vernal equinox, points out that place upon the earth to which the sun is vertical at that time; and from the knowledge of this we obtain the time of its passage over any meridian upon the globe, for every day of the year.

The conformity of the degrees of right ascension, with those of terrestrial longitude, happens but upon one moment of the 24 hours, in a natural day;

when the first point of Aries is on the meridian of London, the first degree of right ascension is on this meridian also; and the signal to confirm this is, when a star of the second magnitude marked γ near the extremity of the wing of Pegasus, is upon the meridian; at that instant, the equinoctial colure will be upon the meridian also; for this colure passes through the first point of Aries and that star.

This is the moment, in which each of the 360 degrees of right ascension in the celestial sphere, is perpendicular to every like degree of terrestrial longitude; at which time there is a perfect parallelism and perpendicular correspondence of all the circles, points, and lines, in both spheres.

To this we have paid a particular regard, in the construction of our new globes, by numbering the degrees on the equator of the terrestrial globe, with an upper row of figures in the same direction, as those of right ascension are numbered upon the celestial globe.

If from that instant of time, when the star γ of Pegasus is upon the meridian, we conceive the stars to be immoveable, and that we, together with the globe of the earth, are turned from west to east upon the equatorial axis, we shall perceive our own meridian to pass successively under every degree and star on the celestial equator.

287. And that the reader may thoroughly understand what is meant by this uniformity in the two spheres, let him imagine the celestial globe to be delineated upon glass, or any other transparent matter, which shall invest or surround the terrestrial globe, but in such a manner, that either may be turned about upon the poles of the world, whilst the other remains fixed; and suppose the first point

of Aries, on the investing globe, to be placed upon the first point of Aries on the terrestrial globe, (which point is in the meridian of London,) they will then represent that situation of the heavens and the earth we have been just describing, on that instant when the first point of Aries is upon the meridian; and then every star on the celestial will lie upon every particular place of the terrestrial globe, to which it is a correspondent; each star will then have the degree of its right ascension directly upon the corresponding degree of terrestrial longitude; their declination will also be the same with the latitude of those places upon which they lie.

Now if the reader conceives the celestial investing globe to be fixed, and the terrestrial globe to be gradually turned from west to east, he will readily understand, as the meridian of London passes from one degree to another under the investing sphere, that every star thereon becomes a correspondent to another place upon the earth; and so on, until the earth has completed one diurnal revolution, or till all the stars, by their apparent daily motion, have passed over every meridian of the terrestrial globe. Hence arises an amazing variety in the harmony of both spheres.

If the sun and a star pass the meridian on any particular day, the next day the star will precede the sun about four minutes; in two days the acceleration of the star with respect to the sun will be about 8 minutes; in 4 days, 16 minutes, in 8 days, 32 minutes, and in 15 days the apparent motion of the star will be accelerated one hour; whilst the sun, with respect to the star, will seem to be retarded one hour; in one month the star will be two hours before the sun, in three months six hours, in six months twelve hours, and in one year twenty-four hours.

So that a year after the sun and star have crossed the meridian together, they will meet again nearly at the same time; but the star, instead of seeming to make 365 revolutions, will have made 366, one more than the earth to the sun in a year.

The right ascension of the first point of Aries, is the complement of the sun's right ascension to 360 degrees of the equator, or to the 24 hours of a natural day: this is the point from which the right ascension of the sun, stars, and planets is always reckoned.

The reader will please to observe, that in spring and summer, the first degree of right ascension, which is the first point of Aries, comes to the meridian with us before noon; there are no stars then visible in the night, but those which follow the first point of Libra; that is to say, those stars which have more than 180 degrees of right ascension: in autumn and winter those stars are visible in the night, which follow the first point of Aries, having less than 180 degrees of right ascension.

Observe also, that the interval between the passage of the first point of Aries over the meridian of any place, and that of the first point of Libra over the same meridian, is not 12 complete hours, but only 11 hours 58 minutes, to which attention must be paid, lest these two minutes should be mistaken.

By the passage of the stars over the meridian, we are taught the knowledge of those degrees of the equator, which are then rising and setting; for that degree which is setting precedes that on the meridian 90 degrees, or six hours; and 180 degrees or twelve hours that which is rising; and that degree of the equator, which is on the meridian under the elevated pole, is 180 degrees distant from that point of it which is passing the meridian.

PROBLEM XLVII. *To find the time of the right ascension of the first point of Aries upon any meridian.*

288. We have already shewn by an easy calculus, how to find the times of equinox to any meridian, but we have not yet shewn their application to the right ascension of the first point of Aries.

The diurnal difference of right ascension, at the time of a vernal equinox, is 3 min. 38 sec. which we have formed into a table, intitled, "The horary difference in the motion of the first point of Aries at the time of a vernal equinox;" to which is annexed, "A table of the difference of the passage of the first point of Aries over the meridian for every day in the year."

THE USE OF THE TABLES OF RIGHT ASCENSION.

289. Having found the time of any vernal equinox, and transferred it from the fixed to your own meridian by the addition of your meridian distance,

Take out of the table of horary differences, the motion answering to the hours and minutes of the time of the vernal equinox, and their sum will be the time of the passage of the first point of Aries over that meridian; the day on which, but before, the equinoctial intersection happens.

N. B. In taking out the numbers from this table, reject the thirds, if they are under thirty; if they exceed thirty, add one to the minutes found in the table.

A. D. 1769, the vernal equinox falls on March 19th, 19 h. 37 min.

		min.	sec.
hours	19	2	53
min.	37	0	6
Right ascension of ♈ ☉, upon the equinoctial day		2	59 past noon.

A. D. 1770, the sun will enter Aries, March 20, 1 h. 26 min.

		min.	sec.
hours	1	0	9
min.	26	0	4
Right Ascension of ♈ ☉, on the equinoctial day, at		0	13 past noon.

A. D. 1771, the vernal equinox falls on March 20, 7 h. 15 min.

		min.	sec.
hours	7	1	4
min.	15	0	2
Right ascension of ♈ ☉, on the equinoctial day, at		1	6 past noon.

A. D. 1772, the sun will enter Aries, March 19, 13 h. 4 min.

		min.	sec.
hours	13	1	58
min.	4	0	1
		1	59

The right ascension of the first point of Aries, thus found for the day on which the equinox happens, holds good for the whole year, and is to be added to the difference of the passage of the first point of Aries over the meridian found against the day of the month; and their sum will be the time of day when the first point of Aries will pass the meridian.

Observe when the equinox falls on the 19th day of March in a year which is not bissextile, to seek the day of the month in the right hand column of the table; and when it falls upon the 20th day of March, seek the day of the month in the left hand column, over which in either case, and under the name of the month, you have the proper difference of right ascension to be added to that found above for the day of the equinox.

In bissextile years, seek the day of the month in the left hand column, to the end of February, and for the intercalary day, or 29th of February, take out the difference of right ascension answering to the first of March, after which to the year's end seek the day of the month in the right hand column.

Having thus found the right ascension of the first point of Aries for any day in the year, add thereto 11 h. 58 min. and you obtain the time of the right ascension of the first point of Libra.

EXAMPLE I.

A. D. 1769, equinox March 19.

	h.	min.	sec.
Jan. 25,	3	23	24
	+	2	59
Right ascension, ♈ ☉,	3	26	23
Nov. 14,	8	36	31
	+	2	59
Right ascension ♈ ☉,	8	39	30

EXAMPLE II.

A. D. 1770, equinox March 20.

	h.	min.	sec.
Feb. 25,	1	24	52
	+	0	13
Right ascension ♈ ☉,	1	25	5
Oct. 18,	10	26	6
	+	0	13
Right ascension ♈ ☉,	10	26	19

EXAMPLE III.

A. D. 1771, equinox March 20.

	h.	min.	sec.
Jan. 12,	4	22	46
	+	1	6
Right ascension ♈ ☉,	4	23	52
Decem. 16,	6	22	58
	+	1	6
Right ascension ♈ ☉,	6	24	4

EXAMPLE IV.

A. D. 1772, equinox March 19.
Bissextile year.

	h.	min.	sec.
Feb. 28,	1	13	35
	+	1	59
Right ascension ♈ ☉,	1	15	34
The intercalary day, Feb. 29,	1	9	50
	+	1	59
Right ascension ♈ ☉,	1	11	49
March 1,	1	6	7
	+	1	59
Right ascension ♈ ☉,	1	8	6
August 28,	13	28	17
	+	1	59
Right ascension ♈ ☉,	13	30	16

These four examples are quite sufficient, if the reader compares them with the tables and precepts.

In the 42d and 43d Problem, Art. 260, 261, we have shewn how to find the hour that any known star comes to the meridian; and also to find the time of the year any star passes the meridian at any hour proposed, but in that place we were not prepared to apply the right ascension of the first point of Aries, so properly for an observation of the stars, as by the following

PROBLEM XLVIII. *To find the time of the right ascension of any star, upon any particular meridian, on any day in the year.*

290. First find the time of the right ascension of the first point of Aries, Art. 288, by Problem 47, agreeable to your own meridian.

Then apply to the celestial globe, and bring the given star under the graduated side of the strong brass meridian, which will cut its right ascension, or rather its distance in time or degrees, upon the equinoctial; add this quantity expressed in time to the right ascension of the first point of Aries, and you will obtain the time of the passage of that star over the meridian very near the truth. Thus,

The star marked γ in the head of Draco, will have 268 degrees, or 17 h. 52 min. of right ascension or distance from the first point of Aries, Art. 276; which added to the right ascension of that point for the 13th day of July, A. D. 1772, gives the true time of its right ascension that evening: at 10 h. 12 min. this star will be over the heads of the inhabitants of London at that time, its declination being 51 deg. 32 min. equal to the latitude of this capital city.

Note. In this method of working, when the hours exceed 24, deduct 24 hours therefrom, and you obtain the true time sought.

PROBLEM XLIX. *To rectify the celestial globe for any time in the evening of any day in the year, by the knowledge of the time when the first point of Aries shall pass the meridian that day.*

291. As the degrees and hours upon the equinoctial line on our new globes, are numbered from the first point of Aries,

First find the right ascension of that point by Problem 47, Art. 288, for the given day, and rectify the globe to your latitude, Art. 189, then bring the first point of Aries upon the globe, under the graduated side of the strong brass meridian, and set the horary index to the hour and minute of the passage of Aries O, first found: turn the globe until the given hour is under the horary index, and place it due north and south by the mariner's compass, attending to the variation of the needle, and you will have a perfect representation of the starry firmament, not only for that instant, but as long as you please to apply yourself to the knowledge of the stars that evening, by only moving the globe to any other minute under the horary index as the time advances.

Thus, on the 25th of February, A.D. 1770, about 46 minutes after V in the evening, the star called Al-debaran, or the Bull's-eye, will be upon the meridian of London, or places adjacent; about VI o'clock that evening, Orion will begin to pass the meridian, and present a glorious view to the eyes of the observer, there being so many eminent stars in that constellation, then successively passing over the meridian until ½ past VII; all the stars in Auriga, or the Charioteer, will be passing the meridian at the same time; after which Canis Major will succeed, with Syrius, the Dog-star, at the side of his jaw; then Canis Minor, and Gemini, or the Twins, will follow, and so on for the remainder of the night.—This appearance may be observed several months, but at different hours in the night, which may be found by this Problem.

Also, on the 8th of May in the same year, the first point of Aries will pass our meridian at 20 h. 58 min. 29 sec. but if we reckon the hours from midnight, at 58 minutes past VIII in the morning, at which time no stars can be seen; therefore we must have recourse to the right ascension of the first point of Libra, which is thus obtained:

	h.	min.	sec.
To the right ascension of the first point of Aries	20	58	29
add	11	58	0
	32	56	29
When the hours exceed 24, subtract therefrom	24	0	0
The right ascension of the first point of Libra, A. D. 1770, May 8th, at - - -	8	56	29 in the evening.

Now in the precept to this Problem, read Libra instead of the word Aries, and the rule will hold good in this as well as in the first case. Therefore,

Bring the first point of Libra to the graduated side of the strong brass meridian, and set the horary index to 56 minutes past VIII in the evening, turn the globe until the horary index points to 10 minutes past X o'clock, and you will find the star called Spica Virginis, being that in the ear of corn she holds in her hand, a star of the first magnitude marked α, upon the meridian at that time. If you then look at the firmament, you will see the constellations Cancer, Leo minor, Leo major, the great Bear, with the head and wings of Virgo on the western side of the meridian; and on the eastern side thereof, the Balance, Scorpio, Bootes, Hercules, &c. successively following the first point of Libra in their passage over the meridian.

THE CORRESPONDENCE OF THE FIXED STARS.

292. Before we attempt an observation of this kind, a signal or warning star must be first obtained; that is, such a star is to be sought, as shall have the same or nearly the same quantity, either in degrees or time of right ascension, reckoned from the first point of Aries, as the place, over which any other star shall then happen to be a correspondent, shall have of longitude, reckoned eastward of London.

It has been shewn, that declination in the celestial, and latitude on the terrestrial, globe, mean one and the same thing, both being measured by their distance from the equator; consequently, if the declination of any star is equal to the latitude of any place, that star, by a line conceived to be drawn from it to the center of the earth, will describe the parallel of that place; whence it becomes a correspondent, not only to that particular place, but also to all those places which lie in the same parallel of latitude, by passing perpendicularly over them all once every 24 hours. But as a preparation, we must first shew, by the following problems, how to find those places to which any star is a correspondent, and those stars which are correspondents to any place.

PROBLEM L. *To find all those places to which any star is a correspondent.*

293. First find the declination of the star on the celestial globe by Problem V. Art. 55, and remember whether it be north or south; count the same number of degrees upon the strong brass meridian of the terrestrial globe the same way from the equator, and note the place by holding the edge of a card thereto; turn the globe from east to west, and all those places which pass under that point, will be correspondents to that star, because they will be in the line passing from the center of the earth through the very place upon its surface, to which the star is at that time vertical. Thus,

The declination of the star marked γ, in the head of Draco, is 51 deg. 32 min. equal to the latitude of London; therefore this brilliant star of the second magnitude may be called the star of this metropolis, without being deprived of its own name; it may likewise take the name of any other place in the parallel of London.

The reverse of this Problem, being to find all the stars which are correspondents to any place, is so easy as to require no farther explication, than that of applying first to the terrestrial globe.

The apparent diurnal motion of one star only, will successively shew its perpendicularity to various countries, as will appear by

A GENERAL DESCRIPTION OF THE PASSAGE OF THE STAR MARKED γ IN THE HEAD OF THE CONSTELLATION DRACO, OVER THE PARALLEL OF LONDON.

294. This eminent star traces the parallel of London, and is a star of perpetual apparition to the inhabitants of the Britannic isles; it comes upon the meridian of London with the 268th degree of right ascension, and is at that time directly perpendicular to, or over the heads of, the people of this city, two minutes of an hour after its warning star marked k in the milky way, has passed the meridian.

Note. This star marked k is the southernmost of a group of five stars, situated between the shoulder of Serpentarius and Sobieski's shield, which in the firmament appear in the form of a Roman V, as may be seen upon the globe.

The declination of our correspondent star γ in the head of Draco, is 51 deg. 32 min. equal to the latitude of London; with which apply to the terrestrial globe, and bring London to the graduated side of the strong brass meridian, and set the edge of a card thereto, holding it to the brass meridian with your right hand, while you gradually turn the globe from west to east with the other hand, and that point of the card which is upon the globe will then represent the intersection of that line upon the surface of the earth, which we have supposed to pass from the center of the earth to the star; and as this point, though at rest, passes over the parallel of London upon the globe, so does the central ray, proceeding from the star, really pass over every point of land,

and sea, upon that part of the earth which is circumscribed by the parallel of London.

Thus you will see the star marked γ, in the head of Draco, pass from London over the road to Bristol, and dart its perpendicular rays upon that city; then crossing the sea, it reaches Ireland between Kinsale and Cork, and leaving that kingdom, will shine over the Atlantic Ocean, until it is perpendicular to the north cape of Newfoundland; whence it will be vertical to Eskimos, and pass between lake Achona and northern coast of the gulph of St. Lawrence, then it will cross St. James's Bay, Kristino, &c. and pass westward over a vast space of land but little known to the Europeans; thence it will leave the western coast of North America, to shine upon the northern part of the Pacific Ocean, until it is perpendicular to several islands, one of which is called St. Abraham; it crosses the southern land of Kamkatska, and the island Sangalien; thence it becomes perpendicular to the continent near Telmen on the east side of Mongales in Chinese Tartary, and so proceeds to cast its perpendicular rays over a vast country in Asia, being sometimes a zenith point to the Chinese, at other times to the Russian Tartars, and passing over Bielgorod, becomes vertical to Muscovy, Poland, Germany, and Zealand, and so crosses the sea again to return to its perpendicularity over the city of London; all which is performed by the earth's diurnal motion in so short a time as twenty-three hours and fifty-six minutes.

When a beginner has been thus exercised with the general passage of two or three principal stars over their correspondent parallels on different parts of the earth, his ideas will be so greatly improved, that maps and charts may then be laid before him with propriety, in order to confirm him in the knowledge of the particular parts of those very parallels, of which he has already attained a general idea upon the globe.

PROBLEM LI. *To find a signal, or warning star, that shall be upon or near the meridian of an observer, at the time any known star is perpendicular to any place on its corresponding parallel.*

295. Bring the given place to the graduated side of the strong brass meridian on the terrestrial globe, and it will cut the degrees of its longitude, reckoned eastward from London, upon the upper row of figures over the equator; then

Apply to the celestial globe, and set the given star under the graduated side of the strong brass meridian, which will cut the degree of its right ascension on the equinoctial.

If the situation of the observer is west of the given place, subtract the terrestrial longitude from the right ascension of the star; if east, add the longitude, and move the celestial globe, till the sum or residue thereof is under the graduated side of the strong brass meridian, and then that side will be directly over those stars which are upon, or have just passed, or are not quite come up, to the observer's meridian, at the moment the given star is vertical to the place proposed; either of which will correctly answer the present purpose, and become the signal or warning star; that upon its arrival on the meridian, will declare the given star to be vertical to the place assigned.

Thus let the observer be in or near London, and the bright star in Lyra, or the harp, of the first magnitude, be given, it is called Vega, and marked α: this star is a correspondent to the south west cape of the island of Sardinia in the Mediterranean.

The longitude of this cape from London is 9 degrees, and the right ascension of the star Vega is 277 degrees, as London is west of Sardinia; 9 degrees subtracted from 277 degrees, leaves 268 degrees of right ascension, to which the celestial globe being set, the graduated side of the strong brass meridian will be found directly over the star γ in Draco, and also over a star of the fourth magnitude in one of the heads of Cerberus. These are eminent signals, and both upon the meridian, when at the same time the star marked θ, in the knee of Hercules, will have passed the meridian about two minutes of an hour, and the star marked P, of the fourth magnitude, in the milky way, will want about two minutes of an hour of coming to it.

Hence when the star marked γ, in the head of Draco, sends forth its perpendicular rays upon the city of London, the star Vega in Lyra will also be perpendicular to the S. W. cape of the island of Sardinia. At which time an observer at London will be sensible of the distance between the zenith of the two places, and may note the bearing of Sardinia from London upon his sensible horizon, to which he may refer at any time in the day.

An observer at Sardinia may note the same with respect to the distance and bearing of London from him.

To excite students who have an aspiring emulation to improve themselves in this extensive science of geography and astronomy, the principal requisites whereby they may acquire universal knowledge, we shall proceed to illustrate this system of the natural agreement between the celestial and terrestrial spheres, by a few interesting examples.

Example I.

WHEN THE STAR MARKED γ IN THE HEAD OF DRACO IS PERPENDICULAR TO THE CITY OF LONDON, THE TWELVE FOLLOWING STARS MAY BE SEEN FROM THENCE AT THE SAME TIME, WHEN THEY WILL ALSO BE PERPENDICULAR TO AS MANY PLACES UPON THE EARTH.

296. The signal or warning star is γ in the head of Draco, which comes upon the meridian with the 268th degree of right ascension; it will be vertical to the city of London two minutes of time after the star marked k, in the milky way, near the equinox, has passed the meridian, at which time the twelve following stars will be vertical to the places they stand against :—

West of London.

Right Asc.		Decl. and Lat.			West Lon.
267½	Knee of Hercules	θ	37	Carthagena, Old Spain	0¼
267½	Wrist of Hercules	ι	30½	Frontiers of Morocco and Targua	0½
261	Ras alhagus, Serpentarius	α	12½	Kingdom Kombergrada, Africa	7
198	Spica Virginis	α	10	Peru, S. America	70
175	Deneb Alasad, Lion's tail	β	16	Chapa in Mexico	93
191	Alioth, 1st in tail Great Bear	ε	57	Isle Belchier, Hudson's Bay	77

East of London.

Right Asc.		Decl. and Lat.			East Lon.
277	Vega, in Lyra	α	38½	S. W. Cape, Isle of Sardinia	9
295	Atair, Eagle's neck	α	8	Frontiers of Benin and Nigritia, Africa	17
290	Swan's beak, Albireo	β	27¼	Mid. Levata in Tagua, Africa	22
308	Deneb, Swan's rump	α	44½	Palmyra	40
343	Sheat, in Pegasus	β	27	Middle of Mogul's Empire	75
309	Swan's So. Wing	ε	33½	Frontiers of Turkey in Asia, and Desert Arabia	41

The use of a warning star is to point out the true time of the phœnomenon, which is to be first nearly found by obtaining the time of the right ascension of that star for the evening on which the observation is intended to be made.

This table of correspondents was formed as follows:

The right ascension and declination of the stars were found in round numbers upon the celestial globe, and written in two columns, inclosing the names of the stars; the columns for the names of the correspondent places being left blank for their insertion afterwards:

Next, as the longitude on our new terrestrial globes is numbered both ways from the meridian of London, whatever the right ascension of the signal star may happen to be, that point of the celestial sphere is likewise considered to be upon the meridian of London. Therefore,

To gain the longitude in the last column of the table, if the given stars were east of the signal, the right ascension of the warning star was subtracted from the right ascension of the given star.

But the west longitude was obtained by subtracting the right ascension of the given stars from that of the signal.

The reverse of this example is to find what stars will be perpendicular to any place upon the earth, a warning star being known, that shall be upon the meridian of an observer, when the stars to be sought shall be vertical to the places assigned, which the reader will easily perform from what has been already said.

When a star is known to be perpendicular to any assigned place, its correspondence to that terrestrial point may be equally affirmed, to all those who can see it at that instant from any part of the earth, or sea, they may then happen to be upon.

If an observer in Palmyra, another in the middle of the Mogul's empire, a third at Levata in Africa, and a fourth at Chapa in Mexico, should look at the star γ, in the head of Draco, the moment it is in the zenith of London, they will see its correspondence to that metropolis at one and the same instant of time; their hour only will be different according to the difference of the meridians, as those places are situated either east or west from London.

The signal or warning star to each of these places, is the perpendicularity of that star expressed in the preceding catalogue of twelve stars.

From the observation under either of these stars in the catalogue, may be seen the other twelve stars, when they are shining over the heads of the inhabitants of all the other countries therein named.

This constitutes the system of astronomical geography before spoken of. It affords us a real assistance from the heavens, whereby we not only see the marvellous distances of a multitude of celestial bodies, composing that part of the universe, which we are permitted to behold; but it also enables us to comprehend the distances and bearings of the most remote countries from that point of the earth upon which we stand.

Example II.

297. When the bright star marked β, in the

head of Castor, is upon the meridian of London with the 110th degree of right ascension, the twelve following correspondents will be vertical to the places annexed :—

WESTWARD.

Right Asc.		Decl. and Lat.			West Lon.
14	Girdle of Andromeda, Mizar	ε	34	Kichuans, Louisiana	96
18	Cassiopea's thigh	δ	59	P. Wales fort, Hudson's Bay	92
27	Almaak, foot of Andromeda	γ	41	Twightees, S. of Lake Michigan	83
42	Shoulder of Perseus	γ	52	Eskimos between L. Otter and L. Pitetibi, North America	68
47	Algenib, Perseus's side	α	49	Cape Risher, G. St. Lawrence	63
76	Rigel, Orion's foot	β	9	Sea and Coast of Olinda	34

EASTWARD.

Right Asc.		Decl. and Lat.			East Lon.
132	Great Bear's foot	κ	47	Middle of Hungary	22
139	Hydra's heart	α	8	Kingdom Massey, Africa	29
143	Corner of the Lion's mouth	ε	25	Nahassa, in Egypt	33
149	Regulus, Lion's heart	α	13	Abyssinia, Africa	39
176	Third in the Sq. Great Bear	γ	53	Ostiakis, S.W part of Siberia	66
192	N. Wing of Virgo Vindematrix	ε	12	Sea 2° E. of Pondicherry	82

These stars are visible in the months of January, February, and March.

Example III.

298. When the bright star marked α in the ear of corn which the Virgin holds in her hand, called Spica Virginis, is upon the meridian of London with 198 degrees of right ascension, the following twelve stars will be vertical to the several places in the following table :—

Westward.

Right Asc.		Decl. and Lat.			W. Lon.
90	First star in the foot of Castor	η	$22\frac{1}{2}$	Isles of Tres Marias, New Spain	108
113	Head of Pollux	β	29	Sea near C. Escondid, Florida	85
139	Hydra's heart	α	$7\frac{1}{2}$	Yamari, a Branch of the Amazonian River	61
149	Regulus, Lion's heart	α	13	Sea 12° E. of the Antilles	49
175	Lion's tail, Alasad	β	16	Near Bonavista, C. Verd Isles	23
191	First in tail Great Bear, Alioth	ε	57	Western Isles of Scotland	7

EASTWARD.

Right Asc.		Decl. and Lat.			E. Lon.
212	N. Hand of Bootes	ι	52	S. of Berlin, in Prussia	14
243	Scorpion's heart	α	25	S. Coast of Madagascar	45
249	In the Back of Hercules	η	39	S. E. of the Caspian Sea	51
277	Vega, in Lyra	α	39	Coten, in Tartary	79
290	Albiero, the Swan's beak	β	28	Toudsang, in Thibet Major	92
294	Atair, in the Eagle	α	8	Eastern Sea, or Coast of Malacca	96

This phœnomenon may be seen in the months of April, May, and June.

EXAMPLE IV.

299. When the 289th degree of right ascension is upon the meridian of London, signified by one minute of an hour after the star marked δ in the southern wing of the Eagle has passed the meridian, then the twelve following places will have the annexed stars in their zenith :—

Westward.

Right Asc.		Decl. and Lat.			W. Lon.
206	The star in the leg of Bootes	η	20	Sea 2° S. Cape Corrente, Cuba	83
219	Southern Scale of Libra	α	15	Collao, in Peru	70
226	Northern Scale of Libra	β	8	Amazonia, America	63
236	A star in Scorpio	π	25	Paraguay, America	53
240	Hand of Serpentarius	δ	3	N. W. part of Brazil	49
267	Knee of Hercules	θ	37	N. of St. Michael, in the Azores	22

Eastward.

Right Asc.		Decl. and Lat.			E. Lon.
321	Side of Cepheus	β	70	Fro. Sea near Isle Wardus, Laponia	32
328	Should. of Aquarius	α	1	Between Sio and Ampaia, Zanguebar	39
331	First in the head of Cepheus	ε	56	Russia, 4° E. of Moscow	42
343	Markab in Pegasus	α	27	Sea Coast in Persian Gulph	54
359	Andromeda's head	δ	27	Tala, Mogul's Empire	70
360	A star in Pegasus	γ	14	Sea near Isle Lakdinas	71

These stars may be observed in the months of July, August, and September.

EXAMPLE V.

300. When the star marked θ in the side of the Whale is upon the meridian of London, with 18 degrees of right ascension, the twelve following stars will be in the zenith of the annexed places:—

WESTWARD.

Right Asc.		Decl. and Lat.			W. Lon.
290	The Swan's beak	β	28	Gulph Mexico, 3° S. Misisippi	88
294	First in the Swan's wing	γ	44	Lake Michigan, Canada	84
308	Deneb, in the Swan's rump	α	44	New England	70
324	Side of Cepheus	β	70	Cumberland near Baffin's Bay	57
331	Head of Cepheus	ε	56	N. Sea, E. of Labrador	47
341	Fomahaut, mouth of Pisces Notius	α	30	Middle of the Atlantic Ocean	37

EASTWARD.

Right Asc.		Decl. and Lat.			E. Lon.
27	Almaak, foot of Andromeda	γ	41	Sea coast of Sardinia	9
42	Shoulder of Perseus	γ	52	Brisac Luthania	24
43	Menkar, Whale's mouth	α	3	Bake Bake, Africa	25
53	The Pleiades		23	Frontiers of Egypt and Nubia	35
96	North foot of Pollux	γ	16	Golconda, Asia	78
112	Procyon, little Dog	α	6	Sea 1° N.W. Achem Sumatra	94

The stars in this example may be seen in the months of October, November, and December.

PROBLEM LII. *The phænomena of the harvest moon.*

301. When the moon is at or near the full, about the time of an autumnal equinox, she rises nearly at the same hour for several nights together: this phœnomenon is called the harvest moon.

To account for this upon the celestial globe, set the artificial sun upon the first point of Libra, where the sun must necessarily be at every autumnal equinox, and place the artificial moon upon the first point of Aries, where she must be, if a full moon should happen at that time.

Rectify the globe to the position of a right sphere, Art. 214, which answers to the inhabitants of the equator; bring the center of the artificial sun to the western edge of the broad paper circle, and the horary index in this case being the graduated edge of the strong brass meridian, will cut the time of the sun's setting, and the moon's rising; hence it is obvious the moon will rise when the sun sets, which will be at VI o'clock, because they are both supposed to be in the celestial equator, but in opposite signs. Therefore on that day the same phœnomenon will happen in all latitudes between the equator and either pole.

But as the moon's motion in her orbit, which we shall at present consider as coincident with the ecliptic, is about 13 deg. 10 min. every day, which retards her diurnal motion about 51 min. 56 sec. of time with respect to the first point of Aries, this daily difference as it relates to the sun is generally reckoned at 48 minutes of time, or two minutes for every hour.

Let us now enquire upon the globe, what time the moon will rise the next night after the autumnal equinox, at which the sun will have advanced one degree in Libra, and the moon 13 deg. 10 min. in Aries, which is 12 degrees more than the sun has done in the same time: therefore place the center of the artificial sun upon the first degree of Libra, and the artificial moon on 13 deg. 10 min. of Aries, the globe being rectified as before to the position of a right sphere, bring the artificial sun under the graduated side of the strong brass meridian, and set the horary index to XII, turn the globe until the artificial sun coincides with the western side of the broad paper circle, the horary index will shew he sets that evening at VI o'clock, and the globe being turned till the artificial moon coincides with the eastern side of the broad paper circle, the horary index will shew the moon's rising that evening to be about 48 minutes past VI o'clock, with 5 degrees of amplitude northerly, as she is now entered into the northern half of the ecliptic.

Now elevate the north pole of the globe to the latitude of London, every other rectification remaining the same, and bring the artificial moon to the east side of the horizon, and the horary index will point to 20 minutes past VI, her time of rising; and her amplitude at that time will be about 8 degrees, 3 degrees more than at the equator the same evening.

If we thus investigate the time of the moon's rising for two or three nights together, before and after the autumnal full moon, it will be found nearly the same.

The reason is, that the full moons which happen at this time of the year, are ascending from the southern into the northern signs of the zodiac: whence the moon describes a parallel to the equator every night more northerly, which increases her rising amplitudes considerably, and more so as the latitude is greater, as in the present example; hence it is plain, that the nearer any celestial object is to either pole, the sooner it ascends the horizon.

Every thing remaining as before, if we elevate the north pole of the globe to $66\frac{1}{2}$ degrees, which is the latitude of the northern polar circle, and bring the artificial moon to the east side of the horizon, she will be found to rise about the same time that the sun sets the evening after the autumnal full moon, which is about VI o'clock, at which time her place and amplitude will be about 13 degrees.

In this position of the globe, if the artificial moon be removed 13 deg. 10 min. upon the ecliptic, which is her mean motion therein for one day, and so on for fourteen nights together, she will be seen to rise within the space of one hour during that time, which will be clear on observing that half the ecliptic rises at once.

It is remarkable that when the moon varies least in the time of her rising, the diurnal differences are greatest at the times of her setting.

What has been said with respect to north latitudes is equally applicable to south latitudes.

In like manner the new moons in spring rise nearly at the same hour for several nights successively, while the full moons rise later by a greater difference than at any other time of the year, because at this time of the year the new moons are in the ascending, and the full moons in the descending signs.

This phœnomenon varies in different years: the moon's orbit being inclined to the ecliptic about 5 degrees, and the line of nodes continually moving retrograde, the inclination of her orbit to the equator will be greater sometimes than at others, which prevents her hastening to the northward, or descending southward in each revolution with equal pace.

PROBLEM LIII. *To find the time of the year in which a star rises or sets cosmically or achronically.*

302. The cosmical rising and setting of a star, is when a star rises with the sun, or sets at the time the sun is rising.

The achronical rising or setting of a star, is when a star rises or sets at the time the sun is setting.

Elevate the pole of the celestial globe to the latitude of the place, and bring the star to the eastern edge of the broad paper circle, and observe what degree of the ecliptic rises with it, which seek in the kalendar on the broad paper circle, against which is the day of the month whereon that star rises cosmically.

Turn the globe till the star coincides with the western edge of the horizon, and that degree of the ecliptic which is cut by the eastern side, gives the day of the month when the star sets cosmically; so likewise against the degree which sets with the star, you have the day of the month of its achronical setting, and if you bring it to the eastern side of the horizon, that degree of the ecliptic then cut by the western side of the broad paper circle sought in the kalendar, will shew the day of the month when the star rises achronically.

PROBLEM LIV. *To find the time of the heliacal rising and setting of a star.*

303. When a star is first visible in the morning, after having been so near the sun as to be hid by the splendor of its rays, it is said to rise heliacally.

When a star is immersed in the evening, or hid by the sun's rays, it is said to set heliacally.

Elevate the pole of the celestial globe to the latitude of the place, bring the star to the eastern side of the broad paper circle, fix the quadrant of altitude to the zenith, and apply its graduated edge to the western side in such a manner that its 12th degree above the horizon may cut the ecliptic, the point opposite to this will be 12 degrees below the broad paper circle on the eastern side, and is the sun's place in the ecliptic at the time a star of the first magnitude rises heliacally; seek this point in the kalendar, or upon the ecliptic line on the globe, against which you will find the day of the year when that star rises heliacally.

To find the heliacal setting, bring the star to the western side of the horizon, and turn the quadrant of altitude on the eastern side, till the 12th degree cuts the ecliptic; its opposite point is the sun's place, which sought either upon the kalendar or ecliptic line, gives the day of the year when the star sets heliacally.

Stars of the first magnitude, according to Ptolemy, rise or set heliacally, when they are 12 degrees distant from the sun; that is, when the star is rising, the sun must be depressed in the perpendicular below the horizon 12 degrees, that the star may be far enough from the sun's rays to be seen before he rises.

Stars of the second magnitude require the sun's depression thirteen degrees, and those of the third magnitude fourteen degrees, &c.

THE MANAZIL AL KAMER OF THE ARABIAN ASTRONOMERS, * FROM ULUGH BEIGH, PUBLISHED AT OXFORD, 1665.

304. The manazil al kamer of the Arabian astronomers, are XXVIII; they are so called, i. e. the mansions of the moon, because they observed the moon to be in or near one of these every night during her monthly course round the earth: they are these that follow, to which upon the globe the Arabian characters are affixed, but omitted here for the want of an Arabian type.

I. *Al Sheratán*, these are the first and second stars of Aries, or the stars in the Ram's horns, marked β and γ, with I, ☾, signifying the first mansion of the moon, which the reader will please to remember once for all.

II. *Botein*, the stars in the Ram's belly, according to Ulugh Beigh; by Bayer, and on our globe, ι and ϱ.

* See the Rev. Mr. Costard's History of Astronomy, p. 19.

III. *Al Thuraiga,* the Pleiades.

IV. *Al Debarân,* the Bull's eye.

V. *Al Heh'a,* the three stars in the head of Orion.

VI. *Al Hen'ah,* the star marked ξ in the left foot of Pollux.

VII. *Al Dira,* the two bright stars, one in the head of Castor, the other in Pollux, marked α and β.

VIII. *Al Nethrah,* the nebulæ, or group of stars in Cancer, marked ε, called by the Greeks φατνη, i. e. Præsepe.

IX. *Al Terphah,* the Lion's eye, marked μ.

X. *Al Geb'ha,* the star in the Lion's mane, marked ζ.

XI. *Al Zub'rah,* the stars in the Lion's rump, marked δ and θ.

XII. *Al Serphah,* the Lion's tail, marked β, called Deneb al asad.

XIII. *Al Awwa,* they are four stars in Virgo, marked η δ θ γ.

XIV. *Simák al A'zal,* the Virgin's spike, marked α.

XV. *Al Gaphr,* three stars in the skirt of the robe of Virgo, marked φ ν κ.

XVI. *Al Zubàna,* that is Libra; the northern scale is called *Zubânah Al Shemali,* and is the star marked β; the southern scale, marked α, is called *Zubânah al Genubi*; Shemali signifies northern, and Genubi southern; they are exactly miscalled on the common globes of modern construction.

XVII. *Al-Iclil,* these are the four stars in Scorpio, marked $\nu\ \beta\ \delta\ \pi$.

XVIII. *Al Kalb,* the Scorpion's heart, marked α more fully, *Kalb Al Akrab.* The word *Antares,* if it is not a corruption, has no signification, and is therefore omitted.

XIX. *Al Shaulah,* the Scorpion's tail, or the star marked λ. The word *Lesath* we have omitted, being another pronunciation of *Lásah,* the true name is *Shaulah.*

XX. *Al Náaim,* these are eight stars in Sagittary, marked $\gamma\ \delta\ \varepsilon\ \lambda\ \mu\ \sigma\ \phi\ \psi$; Ulugh Beigh makes them only three, i. e. $\gamma\ \sigma\ \psi$.

XXI. *Al Beldah,* this is that part of the Horse in Sagittary, where there are no stars drawn, and if there be any in that part of the heavens, it is thought they are only telescopic stars.

XXII. *Sad Al Dábih,* three stars in Capricorn, marked $\alpha\ \beta\ \nu$.

XXIII. *Sad Al Bula,* the star marked ν in the hand of Aquarius.

XXIV. *Sad Al Suúd,* the stars marked β and ζ in Aquarius.

XXV. *Sad Al Achbigah,* three stars in Aquarius marked $\gamma\ \xi\ \theta$.

XXVI. *Al Pherg al Muhaddem,* the stars marked α and β in Pegasus.

XXVII. *Al Pherg al Muáechir,* these are two stars, one in the head of Andromeda, marked δ, the other in the wing of Pegasus, marked γ.

XXVIII. *Al Rishâ*, the star marked β in the girdle of Andromeda.

This is a division of the heavens, different from any thing the Greeks were acquainted with, and therefore was not borrowed from them.

PROBLEM LV. *To find a meridian line.*

305. Bring the sun's place in the ecliptic on the celestial globe, to the graduated side of the strong brass meridian, and set the horary index to that XII which is most elevated; turn the globe, till the star marked γ in Cassiopea's hip, is under the graduated side of the strong brass meridian, with about 11 degrees of right ascension; at which time the polar star, in the extremity of the tail of the little bear, will be above the pole, and upon the meridian also. If you find in this application of the globe, that the horary index points to any hour of the day, when the globe is rectified to the latitude of your situation, turn the globe again, till the star marked ϵ, called Alioth, being the first in the tail of the great Bear, is under the graduated side of the strong brass meridian, and then the polar star will likewise be upon the meridian, with about 191 degrees of right ascension, but under the north pole, and the horary index will point out the time of the night, when this phœnomenon is to happen; before which you are to have the following apparatus properly prepared, that you may be ready to attend the observation, that is, to find your meridian line.

Suspend two plumb lines, and let their weights be immersed in water, to prevent their vibrating, but in such a manner that the string of one of them may be directly between the polar star and the string of the other. After this adjustment of the two strings, if they remain untouched till the next day at noon, a meridian line may be obtained at any window in the house which has a southern aspect, by suspending lines as above from the ceiling; that next the window may be fixed, but the other should be moveable in a direction nearly east and west; the weights of these ought also to be immersed in water: then, if two persons attend a little before noon on the next day, one of them at the two first plumb lines which were adjusted to the polar star, and the other at the two plumb lines in the house which are then to be adjusted, each of them holding a sheet of white paper in their hands, to receive the shadow of the two strings cast thereon by the sun; the first observer is to give a signal to the second of the instant the two shadows on his paper are united in one and the same line, at which time the sun will be precisely upon the meridian. The other observer in the house is likewise to attend with diligence, and as the sun is coming nearer and nearer to the meridian, he is constantly to remove his moveable plumb line, and keep the shadows of his two strings always united in one distinct shadow, that his observation may be complete, when his assistant gives the definitive signal.

If this be repeated four or five times, a very accurate meridian line may be obtained, and may be drawn on the window, the floor, or a pavement, by their shadow when united by the sun's rays, and the plumb lines may be occasionally suspended from two fixed hooks, when you chuse to observe the passage of the stars across the meridian.

For the use of the curious it will not be improper to observe, that the late Dr. Bradley found that the distance of the star marked α at the extremity of the tail of the little Bear, from the polar point, was 2 deg. 1 min. 39 sec. on the first of January, A. D. 1751, old style; at the same time its right ascension was $10^\circ 45' 15''$, equal to 43 min 1 sec. of time; and as the right ascension increases 1 min. 16 sec. every ten years, its right ascension may be obtained for any succeeding year; and having the sun's right ascension in time also, subtract the last from the first; by adding 24 hours to the right ascension of the pole star when it is less than the sun's, the remainder will be the time of the star's coming to the meridian.

Then, as before, hang up two plumb lines, between your eye and the polar star.

Problem LVI. *Of the equation of time.*

306. As time flows with great regularity, it is impossible to measure it accurately, and compare its several intervals with each other, but by the motion of some of the heavenly bodies, whose progress is as uniform and regular as itself.

Ancient astronomers looked upon the sun to be sufficiently regular for this purpose; but by the accurate observations of later astronomers, it is found that neither the days, nor even the hours, as measured by the sun's apparent motion, are of an equal length, on two accounts:

1st, A natural or solar day of 24 hours, is that space of time the sun takes up in passing from any particular meridian to the same again*; and one revolution of the earth, with respect to a fixed star, is performed in 23 hours, 56 minutes, 4 seconds; therefore the unequal progression of the earth through her elliptical orbit, (as she takes almost eight days more to run through the northern half of the ecliptic, than she does to pass through the southern,) is the reason that the length of the day is not exactly equal to the time in which the earth performs its rotation about its axis.

2dly, From the obliquity of the ecliptic to the equator, on which last we measure time; and as equal portions of one do not correspond to equal portions of the other, the apparent motion of the sun would not be uniform; or, in other words, those points of the equator which come to the meridian, with the place of the sun on different days, would not be at equal distances from each other.

This last is easily seen upon the globe, by bringing every tenth degree of the ecliptic to the graduated side of the strong brass meridian, and you will find that each tenth degree on the equator will not come thither with it, but in the following order from ♈ to ♋, every tenth degree of the ecliptic comes sooner to the strong brass meridian than their corresponding 10ths on the equator; those in the second quadrant of the ecliptic, from ♋ to ♎, come later, from ♎ to ♑ sooner, and from ♑ to Aries later, whilst those at the beginning of each quadrant come to the meridian at the same time; therefore the sun and clock would be equal at these four times, if the sun was not longer in passing through one half of the ecliptic than the other, and the two inequalities joined together, compose that difference which is called the equation of time.*

These causes are independent of each other; sometimes they agree, and at other times are contrary to one another.

The time marked out by an uniform motion is called true time, and that shewn by the sun is called apparent or solar time, and their difference is the equation of time.

WE NOW PROCEED TO SHEW HOW THE TERRESTRIAL GLOBE WILL REPRESENT THE REAL PHŒNOMENA RELATING TO THE EARTH, WHEN ACTUALLY COMPARED WITH THE REFULGENT RAYS EMITTED FROM THE GREAT SPHERE OF DAY.

307. The meridians on our new terrestrial globes, being secondaries to the equator, are also hour circles, and are marked as such with Roman figures under the equator, and at the polar circles. But observe, there is a difference in the figures placed to the same hour circle; if it cuts the IIId hour upon the polar circles, it will cut the IXth hour upon the equator, which is six hours later, and so of all the rest.

Through the great Pacific sea, and the intersection of Libra, is drawn a broad meridian from pole to pole, it passes through the XIIth hour upon the equator, and the VIth hour upon each of the polar circles; this hour circle is graduated into degrees and parts, and numbered from the equator towards either pole.

There is another broad meridian passing through the Pacific sea, at the IXth hour upon the equator, and the IIId hour upon each polar circle; this contains only one quadrant, or 90 degrees, the numbers annexed to it begin at the northern polar circle, and end at the tropic of Capricorn.

Here we must likewise observe, there are 23 concentric circles drawn upon the terrestrial globe within the northern and southern polar circles, which for the future we shall call polar parallels; they are placed at the distance of one degree from each other, and represent the parallels of the sun's declination, but in a different manner from the 47 parallels between the tropics.

The following Problems require the globe to be placed upon a plane that is level, or truly horizontal, which is easily attained, if the floor, pavement, gravel-walk in the garden, &c. should not happen to be horizontal.

A flat seasoned board, or any box which is about two feet broad, or two feet square, if the top be perfectly flat, will answer the purpose, the upper surface of either may be set truly horizontal, by the help of a pocket spirit level, or plumb rule, if you raise or depress this or that side by a wedge or two, as the spirit level shall direct; if you have a meridian line drawn on the place over which you substitute this horizontal plane, it may be readily transferred from thence to the surface just levelled; this being done, we are prepared for the solution of the following Problems.

PROBLEM LVII. *To observe the sun's altitude by the terrestrial globe, when he shines bright, or when he can but just be discerned through a cloud.*

308. Consider the shade of extuberancy, which is

that caused by the sphericity of the globe, heretofore called the edge of the earth's enlightened disc, and there represented by the broad paper circle, but here realized by the natural light of the sun itself.

Elevate the north pole of the globe to 66½ degrees, bring that meridian or hour circle, which passes through the IXth hour upon the equator, under the graduated side of the strong brass meridian, the globe being now set upon the horizontal plane; turn it about thereon, frame and all, that the shadow of the strong brass meridian may fall directly under itself, or in other words, that the shade of its graduated face may fall exactly upon the aforesaid hour circle; at that instant the shade of extuberancy will touch the true degree of the sun's altitude upon that meridian, which passes through the IXth hour upon the equator, reckoned from the polar circle, the most elevated part of which will then be in the zenith of the place where this operation is performed, and is the same whether it should happen to be either in north or south latitude.

Thus we may, in an easy and natural manner, obtain the altitude of the sun, at any time of the day, by the terrestrial globe; for it is very plain, when the sun rises, he brushes the zenith and nadir of the globe by his rays; and as he always illuminates half of it, (or a few minutes more, as his globe is considerably larger than that of the earth,) therefore when the sun is risen a degree higher, he must necessarily illuminate a degree beyond the zenith, and so on proportionably from time to time.

But as the illuminated part is somewhat more than half, deduct 13 minutes from the shade of extuberancy, and you have the sun's altitude with tolerable exactness.

If you have any doubt how far the shade of extuberancy exactly reaches, hold a pin, or your finger, on the globe, between the sun and point in dispute, and where the shade of either is lost, will be the point sought.

WHEN THE SUN DOES NOT SHINE BRIGHT ENOUGH TO CAST A SHADOW.

309. Turn the meridian of the globe toward the sun, as before, or direct it so that it may lie in the same plane with it, which may be done if you have but the least glimpse of the sun through a cloud; hold a string in both hands, it having first been put between the strong brass meridian and the globe: stretch it at right angles to the meridian, and apply your face near to the globe, moving your eye lower and lower, till you can but just see the sun: then bring the string held as before to this point upon the globe, that it may just obscure the sun from your sight, and the degree on the aforesaid hour circle, which the string then lies upon, will be the sun's altitude required, for his rays would shew the same point if he shone out bright.

Note. The moon's altitude may be observed by either of these methods, and the altitude of any star by the last of them.

PROBLEM LVIII. *To place the terrestrial globe in the sun's rays, that it may represent the natural position of the earth, either by a meridian line, or without it.*

310. If you have a meridian line, set the north and south points of the broad paper circle directly over it, the north pole of the globe being elevated to the latitude of the place, and standing upon a level plane, bring the place you are in under the graduated side of the strong brass-meridian, then the poles and parallel circles upon the globe will, without sensible error, correspond with those in the heavens, and each point, kingdom, and state, will be turned towards the real one which it represents.

If you have no meridian line, then the day of the month being known, find the sun's declination as before instructed, which will direct you to the parallel of the day, amongst the polar parallels, reckoned from either pole towards the polar circle; which you are to remember.

Set the globe upon your horizontal plane in the sun-shine, and put it nearly north and south by the mariner's compass, it being first elevated to the latitude of the place, and the place itself brought under the graduated side of the strong brass meridian: then move the frame and globe together, till the shade of extuberancy, or term of illumination, just touches the polar parallel for the day, and the globe will be settled as before; and if accurately performed, the variation of the magnetical needle will be shewn by the degree to which it points in the compass box.

And here observe, if the parallel for the day should not happen to fall on any one of those drawn upon the globe, you are to estimate a proportionable part between them, and reckon that, the parallel of the day. If we had drawn more, the globe would have been confused.

The reason of this operation is, that as the sun illuminates half the globe, the shade of extuberancy will constantly be 90 degrees from the point wherein the sun is vertical.

If the sun be in the equator, the shade and illumination must terminate in the poles of the world; and when he is in any other diurnal parallel, the terms of illumination must fall short of, or go beyond either pole, as many degrees as the parallel which the sun describes that day, is distant from the equator; therefore when the shade of extuberancy touches the polar parallel for the day, the artificial globe will be in the same position, with respect to the sun, as the earth really is, and will be illuminated in the same manner.

PROBLEM LIX. *To find naturally the sun's declination, diurnal parallel, and his place thereon.*

311. The globe being set upon an horizontal plane, and adjusted by a meridian line or otherwise, observe upon which or between which polar parallel the term of illumination falls; its distance from the pole is the degree of the sun's declination; reckon this distance from the equator among the

larger parallels, and you have the parallel which the sun describes that day; upon which if you move a card, cut in the form of a double square, until its shadow falls under itself, you will obtain the very place upon that parallel over which the sun is vertical at any hour of that day, if you set the place you are in under the graduated side of the strong brass meridian.

Note. The moon's declination, diurnal parallel and place, may be found in the same manner. Likewise when the sun does not shine bright, his declination, &c. may be found by an application in the manner of Problem 57.

PROBLEM LX. *To find the sun's azimuth naturally.*

312. If a great circle at right angles to the horizon passes through the zenith and nadir, and also through the sun's center, its distance from the meridian in the morning or evening of any day, reckoned upon the degrees on the inner edge of the broad paper circle, will give the azimuth required.

METHOD I.

313. Elevate either pole to the position of a parallel sphere, by bringing the north pole in north latitude, and the south pole in south latitude, into the zenith of the broad paper circle, having first placed the globe upon your meridian line, or by the other method before prescribed;

hold up a plumb line so that it may pass freely near the outward edge of the broad paper circle, and move it so that the shadow of the string may fall upon the elevated pole; then cast your eye immediately to its shadow on the broad paper circle, and the degree it there falls upon is the sun's azimuth at that time, which may be reckoned from either the south or north points of the horizon.

Method II.

314. If you have only a glimpse, or faint sight of the sun, the globe being adjusted as before, stand on the shady side, and hold the plumb line on that side also, and move it till it cuts the sun's center, and the elevated pole at the same time, then cast your eye towards the broad paper circle, and the degree it there cuts is the sun's azimuth, which must be reckoned from the opposite cardinal point.

Problem LXI. *To shew that in some places of the earth's surface, the sun will be twice on the same azimuth in the morning, twice on the same azimuth in the afternoon; or, in other words,*

315. When the declination of the sun exceeds the latitude of any place, on either side of the equator, the sun will be on the same azimuth twice in the morning, and twice in the afternoon.

Thus, suppose the globe rectified to the latitude of Antigua, which is in about 17 deg. of north latitude, and the sun to be in the beginning of Cancer, or to have the greatest north declination; set the quadrant of altitude to the 21st degree north of the east in the horizon, and turn the globe upon its axis, the sun's center will be on that azimuth at 6h. 30 min. and also at 10h. 30 min. in the morning. At 8h. 30 min. the sun will be as it were stationary with respect to its azimuth for some time; as will appear by placing the quadrant of altitude to the 17th degree north of the east in the horizon. If the quadrant be set to the same degrees north of the west, the sun's center will cross it twice as it approaches the horizon in the afternoon.

This appearance will happen more or less to all places situated in the torrid zone, whenever the sun's declination exceeds their latitude; and from hence we may infer, that the shadow of a dial, whose gnomon is erected perpendicular to an horizontal plane, must necessarily go back several degrees on the same day.

But as this can only happen within the torrid zone, and as Jerusalem lies about 8 degrees to the north of the tropic of Cancer, the retrocession of the shadow on the dial of Ahaz at Jerusalem was, in the strictest signification of the word, miraculous.

Problem LXII. *To observe the hour of the day in the most natural manner, when the terrestrial globe is properly placed in the sun-shine.*

316. There are many ways to perform this

operation with respect to the hour, three of which are here inserted, being general to all the inhabitants of the earth; a fourth is added peculiar to those of London, which will answer, without sensible error, at any place not exceeding the distance of 60 miles from this capital.

1ST, BY A NATURAL STILE.

317. Having rectified the globe as before directed, and placed it upon an horizontal plane over your meridian line, or by the other method, hold a long pin upon the illuminated pole in the direction of the polar axis, and its shadow will shew the hour of the day amongst the polar parallels.

The axis of the globe being the common section of the hour circles, is in the plane of each; and as we suppose the globe to be properly adjusted, they will correspond with those in the heavens; therefore the shade of a pin, which is the axis continued, must fall upon the true hour circle.

2DLY, BY AN ARTIFICIAL STILE.

318. Tie a small string with a noose round the elevated pole, stretch its other end beyond the globe, and move it so that the shadow of the string may fall upon the depressed axis; at that instant its shadow upon the equator will give the solar hour to a minute.

But remember, that either the autumnal or vernal equinoctial colure must first be placed under the graduated side of the strong brass meridian before you observe the hour, each of these being marked upon the equator with the hour XII.

The string in this last case being moved into the plane of the sun, corresponds with the true hour circle, and consequently gives the true hour.

3DLY, WITHOUT ANY STILE AT ALL.

319. Every thing being rectified as before, look where the shade of extuberancy cuts the equator, the colure being under the graduated side of the strong brass meridian, and you obtain the hour in two places upon the equator, one of them going before, and the other following the sun.

Note. If this shade be dubious, apply a pin or your finger as before directed.

The reason is, that the shade of extuberancy being a great circle, cuts the equator in half, and the sun, in whatsoever parallel of declination he may happen to be, is always in the pole of the shade; consequently the confines of light and shade will shew the true hour of the day.

4THLY, PECULIAR TO THE INHABITANTS OF LONDON, AND ITS ENVIRONS, WITHIN THE DISTANCE OF SIXTY MILES.

320. The globe being every way adjusted as before, and London brought under the graduated side of the strong brass meridian, hold up a plumb line, so that its shadow may fall upon the zenith point, (which in this case is London itself,) and the shadow of the string will cut the parallel of the

day upon that point to which the sun is then vertical, and that hour circle upon which this intersection falls, is the hour of the day; and as the meridians are drawn within the tropics at 20 minutes distance from each other, the point cut by the intersection of the string upon the parallel of the day, being so near the equator, may, by a glance of the observer's eye, be referred thereto, and the true time obtained to a minute.

The plumb line thus moved is the azimuth, which, by cutting the parallel of the day, gives the sun's place, and consequently the hour circle which intersects it.

From this last operation results a corollary, that gives a second way of rectifying the globe to the sun's rays.

If the azimuth and shade of the illuminated axis agree in the hour when the globe is rectified, then making them thus to agree must rectify the globe.

Corollary.

ANOTHER METHOD TO RECTIFY THE GLOBE TO THE SUN'S RAYS.

321. Move the globe till the shadow of the plumb line, which passes through the zenith, cuts the same hour on the parallel of the day, that the shade of the pin held in the direction of the axis falls upon, amongst the polar parallels, and the globe is rectified.

The reason is, that the shadow of the axis represents an hour circle; and by its agreement in the same hour, which the shadow of the azimuth string points out, by its intersection on the parallel of the day, it shews the sun to be in the plane of the said parallel; which can never happen in the morning on the eastern side of the globe, nor in the evening on the western side of it, but when the globe is rectified.

This rectification of the globe, is only placing it in such a manner that the principal great circles, and points, may concur and fall in with those of the heavens.

The many advantages arising from these capital problems relating to the placing of the globe in the sun's rays, an intelligent reader will easily discern, and readily extend to his own as well as to the benefit of his pupil.

Problem LXIII. *To find when the planet Venus is a morning or an evening star.*

322. Rectify the celestial globe to the latitude and sun's place, Art. 189, 190, find the place of Venus by an ephemeris, and set the artificial moon to that place in the zodiac, which will represent the planet; bring the artificial sun to the eastern edge of the horizon; if Venus is then elevated, she will rise before the sun, and be a morning star; but if she is depressed below the horizon, she must then consequently follow the sun, and become an evening star.

Problem LXIV. *To find at what time of the night any planet may be viewed with a reflecting telescope.*

323. Rectify the celestial globe to the latitude

and sun's place, Art. 189, 190, seek the planet's place and latitude in an ephemeris; to which place in the zodiac set the artificial moon to represent the planet, and it will shew its place in the heavens: bring the planet's representative to the eastern side of the horizon, and the horary index will shew the time of its rising; if the artificial sun is then elevated, the planet will not be visible at that time by means of his superior light; therefore turn the globe from east to west until the artificial sun is depressed below the circle of twilight, Art. 93, and 216, where stop the globe, and screw the nut of the quadrant of altitude in the zenith, Art. 192, lay its graduated edge on the center of the planet, and it will shew in the horizon the azimuth or point of the compass, on which the planet may then be viewed in the heavens; the horary index will at the same time point out the hour of the night. When the planet comes to the strong brass meridian, the index will shew the time of its passage over that celestial circle; and at the western edge of the horizon, the time of its setting will likewise be obtained.

Problem LXV. *To find what azimuth the moon is upon at any place when it is flood or high water; and thence the high tide for any day of the moon's age at the same place.*

324. Having observed the hour and minute of high water about the time of new or full moon, rectify the globe to the latitude and sun's place, Art. 189, 190, find the moon's place and latitude in an ephemeris, to which set the artificial moon,

and screw the quadrant of altitude in the zenith; turn the globe till the horary index points to the time of flood, and lay the quadrant over the center of the artificial moon, and it will cut the horizon in the point of the compass upon which the moon was, and the degrees on the horizon contained between the strong brass meridian and the quadrant, will be the moon's azimuth from the south.

TO FIND THE TIME OF HIGH WATER AT THE SAME PLACE.

325. Rectify the globe to the latitude and zenith, find the moon's place by an ephemeris for the given day of her age, or day of the month; and set the artificial moon to that place in the zodiac; put the quadrant of altitude to the azimuth before found, and turn the globe till the center of the artificial moon is under its graduated edge, and the horary index will point to the time of the day on which it will be high water.

THE USE

OF THE

GLOBES

IN THE SOLUTION OF

RIGHT ANGLED SPHERICAL TRIANGLES.

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326. A spherical triangle is formed upon the surface of a globe by the intersection of the three great circles.

327. A spherical angle is the intersection of two great circles that incline to one another; the quantity of any spherical angle is measured by a third great circle, intercepted between the legs of the angle, at 90 degrees distance from the intersecting point.

328. A right angled spherical triangle hath one right angle, the sides about which are called legs, and the side opposite to it the hypothenuse.

329. An oblique angled spherical triangle has its angles greater or less than 90 degrees: the solution of spherical triangles consists in finding the measure of its sides and angles.

330. The sides of any spherical triangle may be changed into angles, and the angles into sides; if for any one side, and its opposite angle, their complement to a semicircle be taken.

Case I.

Problem LXVI. *The hypothenuse and one leg being given, to find the rest.*

In the right angled spherical triangle A B C, fig. 29, are given

		°	′				
The hypothenuse	BC	64	40	to find	the leg		BA
The leg	AC	42	12		the angles		ACB
							CBA

331. Fig. 30. Elevate the pole P to 42° 12′, the quantity of the given leg A C, and number the same quantity on the strong brass meridian from Æ, the equator, to Z, the zenith; there fix the quadrant of altitude. Bring that meridian which passes through London under the brass meridian, and count 64° 40′, the measure of the hypothenuse, on the quadrant downwards from Z to G, and move it till the point G intersects the equator, and the triangle Z G Æ will be formed.

The side Æ Z represents the given side A C, the hypothenuse B C is represented by the arch Z G, the required side A B is represented by G Æ an arch of the equator, its measure 54° 43′, between Æ and G, is the quantity sought; the angle A C B, is represented by the angle G Z Æ, and its measure is found on the arch A O of the horizon equal to 64° 35′.

332. To find the other angle A B C, having obtained the measure of the side B A, 54° 43′, elevate the pole P agreeable thereto, and reckon the same from Æ to Z; there fix the quadrant of

Fig. 30.

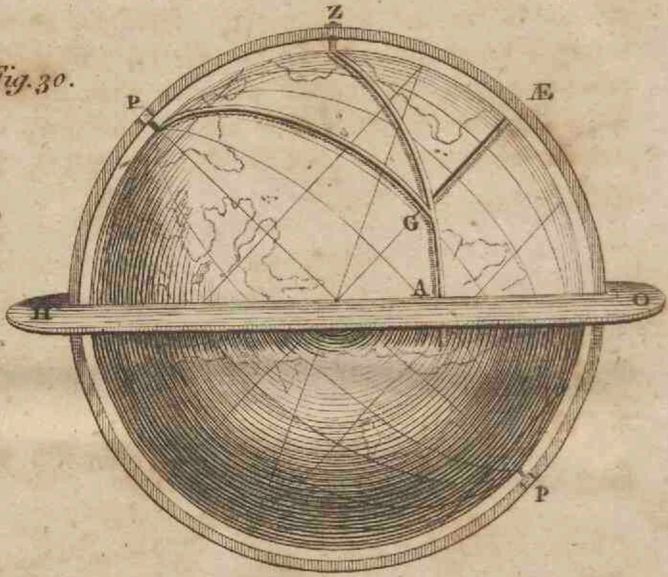


Fig. 29.

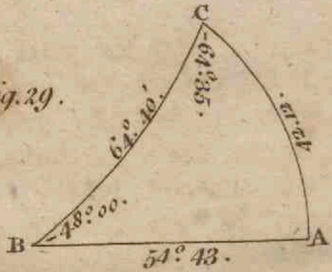


Fig. 31.

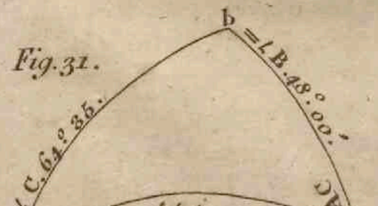
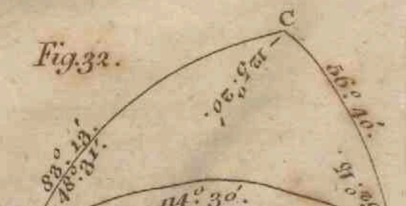


Fig. 32.



Goodnight fe

altitude; number the other leg A C, 42° 12′ from Æ to G on the equator, (the meridian passing through London remaining as before,) and to that point bring the quadrant of altitude; then the arch A O, on the horizon, will contain 48° 00′, the measure of the angle Æ Z G, equal to A B C, the angle sought.

CASE II.

PROBLEM LXVII. *The hypothenuse and an angle being given, to find the rest.*

In the right angled triangle A B C, fig. 29, are given

		°	′		
The hypothenuse	B C	64	40	to find	the angle ABC
The angle	ACB	64	35		the legs AB, AC

333. Fig. 33. Place P p the poles of the globe in the horizon H O, and fix the quadrant of altitude to Z the zenith; number 64° 35′, the measure of the given angle, upon the horizon from Æ to F; move the quadrant to the point F, and thereon count 64° 40′, the quantity of the hypothenuse from Z downwards to G, to which point bring that graduated meridian which passes through Libra ♎, and the triangle G Z ♎ will be formed.

Z G an arch of the quadrant of altitude represents the hypothenuse; Z ♎ an arch of the equator represents the required side A C equal to 42° 12′, and G ♎ an arch of the meridian; P ♎ p equal to

54° 43′, is the measure of the other required side A B.

Now having found the side A B, adjacent to the required angle A B C, its measure may be found by Art. 332.

Case III.

Problem LXVIII. *A leg and its adjacent angle being given, to find the rest.*

In the right angled triangle A B C, fig. 29, are given

		°	′			
The leg	BA	54	43	to find	the leg	AC
The angle	ABC	48	00		angle	ACB
					hyp.	BC

334. Fig. 30. Elevate the pole P, to 54° 43′, the quantity of the given leg B A; count the same from Æ to Z, and fix the quadrant at Z; bring that meridian which passes through London under the strong brass meridian, and reckon the given angle 48° 00′, from O to A, on the horizon; bring the quadrant to A, and the triangle Z G Æ will be formed.

We have the measure of the required side C A upon Æ G an arch of the equator, equal to 42° 12′, and the hypothenuse B C, upon G Z, an arch of the quadrant, equal to 64° 40′, the angle A C B may be found by Art. 332.

Case IV.

Problem LXIX. *Both legs given, to find the rest.*

In the right angled triangle A B C, fig. 29, are given

		°	′				
The legs	AB	54	43	to find	the hyp.		CB
	AC	42	12		the angles		ACB
							ABC.

335. Fig. 30. Elevate the globe to the quantity of either given leg as A C, 42° 12′, number the same from Æ to Z, and fix the quadrant at Z, set the meridian which passes through London under the strong brass meridian, and count the other given leg A B, 54° 43′, upon the equator from Æ to G, bring the quadrant to G, and the triangle Z G Æ will be formed.

The arch Z G on the quadrant of altitude 64° 40′ is equal to B C the hypothenuse, the arch O A, 64° 35′ on the horizon, is the measure of the angle G Z Æ, equal to the required angle A B C. The other angle may be found by Art. 332.

Case V.

Problem LXX. *Both angles given, to find the three sides.*

In the right angled triangle A B C, fig. 29. are given

		°	′				
The angles	ACB	64	35	to find	the hyp.		BC
	ABC	48	00		the sides		AC
							BC

336. In this fifth case, we must have recourse to Art. 330, and then we shall have an oblique angled spherical triangle a b c, fig. 31, whose side a b is equal to the angle A C B of the given triangle; the side b c, equal to the angle A B C; and the side a c, equal to the complement of the right angle to 180 degrees, which must therefore necessarily be 90 degrees.

337. Fig. 30. Number 48° 00′ the side b c of this second triangle, from P, the pole of the globe to Z, and there fix the quadrant of altitude; then bring the point Z into the zenith, Art. 192, and count 90° 00′ the quantity of the side a c, from P the pole to G, upon that meridian which passes through ♎; number the side a b, 64° 35′ upon the quadrant of altitude downwards from Z to G, then move the globe and the quadrant, until these quantities meet in one point at G, and the triangle P Z G will be formed.

The arch Æ G, on the equator, will give the measure of the angle Æ P G 54° 43′, equal to the required side A B; and the arch A O, in the horizon, that of the angle G Z Æ 64° 40′, which is the complement of the angle P Z G to 180 degrees, and is equal to the hypothenuse B C: thus having obtained the measures of two of the required sides, we have sufficient data to find the third side A C, either by the first or second of the preceding cases, Art. 331, 333.

THE USE OF THE GLOBES IN THE SOLUTION OF OBLIQUE ANGLED SPHERICAL TRIANGLES.

CASE I.

PROBLEM LXXI. *Two sides and an angle opposite to one of them being given, to find the rest.*

In the oblique angled spherical triangle BCD, fig. 32, are given

		°	′			
The sides	BC	83	13	to find	the side	BD
	CD	56	40		the angles	BCD
The angle	CBD	48	31			BDC

338. Fig. 30. Count the side BC 83° 13′, on the strong brass meridian from P to Z; fix the quadrant of altitude at Z, and bring that point into the zenith; and from Z downwards to G, number 56° 40′; where make a mark for the extent of the other side CD, and reckon its opposite angle DBC, 48° 31′, on the equator from the point ♎ at G eastward, towards Æ, where stop the globe, and bring the mark upon the quadrant to coincide at G with the meridian PG, which passes through ♎, then the arch PG will contain 114° 30′, the measure of the required side BD; and the arch HA in the horizon 125° 20′, will be the measure of the angle BCD; the other angle PGZ, equal to the required angle BDC, may be found by Art. 332, in changing the sides upon the globe. Or,

339. If you make a mark on the globe directly under the point Z, and bring the point G to the

zenith, over which the quadrant of altitude is to be fixed, and lay its graduated edge upon the point just marked; it will shew in the horizon, between the strong brass meridian and quadrant, 62° 51′, the measure of the required angle P G Z, equal to the angle B D C.

Case II.

Problem LXXII. *Two angles and a side opposite to one of them being given, to find the rest.*

In the oblique angled triangle B C D, fig. 32, are given

		°	′			
The angles	BCD	125	20	to find	the sides	CD
	BDC	62	51			BD
The side	BC	83	13		the angle	DBC

340. Fig. 30. Reckon the angle B D C, 62° 51′, which is opposite to the given side upon the equator from ♎ eastwards, and bring that point to Æ; count the given side B C, 83° 13′ upon the quadrant of altitude from Z downwards to G, where make a mark, and number the other given angle B C D 125° 30′, in the horizon from H to A; set the lower end of the quadrant to the point A, and hold it there while you slide the pole of the globe higher or lower, until the mark on the quadrant at G, intersects that meridian which passes through ♎, and at the same time, that the nut at the upper end of it may be exactly in the zenith, where fix it, and the triangle P Z G will be formed.

The arch P Z, of the strong brass meridian, contains 56° 40′, the quantity of the required side C D, and the arch P G 114° 30′, is equal to the other required side B D, the angle D B C may be found by Art. 332, or 339.

Case III.

Problem LXXIII. *Two sides and their contained angle given, to find the rest.*

In the oblique angled triangle B C D, fig. 32, are given

		°	′			
The sides	BC	83	13	to find	the side	BD
	DC	56	40		the angles	DBC
The angle	BCD	125	30			BDC

341. Fig. 30. Count the side C D 56° 40′ from P to Z on the strong brass meridian; bring the point Z into the zenith, and to it fix the quadrant of altitude, and number from Z downwards to G, the quantity of the side B C 83° 13′, and there make a mark; then count the given angle B C D, 125° 30′, on the horizon from H to A, and to A bring the quadrant; lastly, bring the meridian which passes through ♎ to the point G marked on the quadrant, and the arch P G, 114° 30′ will be the measure of the required side B D, and the equatorial arch Æ G, 63° 51′ is the measure of the angle B D C, equal to the angle G P Z: the other angle may be found as before shewn, Art. 332, 339.

Case IV.

Problem LXXIV. *Two angles and the included side given, to find the rest.*

In the oblique angled triangle BCD, fig. 32, are given

		°	′			
The side	CD	56	40	to find	the angles	DBC
The angles	BCD	125	30		the sides	BC
	BDC	62	51			BD

342. Fig. 30. Number the side CD, 56° 40′, from P to Z, and bring Z into the zenith, and fix the quadrant there also; count the angle BDC, 62° 51′ on the equator, from ♎ to Æ; number the angle BCD, 125° 30′ upon the horizon from H to A, and bring the quadrant to A; then PG, 114° 30′, will be equal to BD the required side, GZ 83° 13′ equal to the other required side BC, and the angle PGZ equal to the angle DBC, may be found by Art. 332, 339.

Case V.

Problem LXXV. *Three sides given, to find the angles.*

In the oblique angled triangle BCD, fig. 32; are given

		°	′		
The sides	BC	83	13	to find the angles	BCD
	CD	56	40		CDB
	BD	114	30		DBC

343. Fig. 30. Number the side C D 56° 40′, on the strong brass meridian from P to Z, bring Z into the zenith, and to it fix the quadrant of altitude; count the side B D, 114° 30′ on the meridian, which passes through ♎ from P to G, and the side C B 83° 13′ upon the quadrant from Z downwards to G, then move the globe and quadrant, until the two last points coincide. The arch H A 125° 20′ on the horizon will be the measure of the angle P Z G, equal to the required angle B C D, the arch Æ S of the equator 82° 15′, is the measure of the angle G P Z, equal to the angle B D C. Thus having found two of the required angles, the third may be found by Art. 332, 339.

Case VI.

Problem LXXVI. *The angles given, to find the sides.*

In the oblique angled triangle B C D, fig. 32, are given

		°	′		
The angles	BCD	125	20	to find the sides	BC
	CDB	62	51		CD
	DBC	48	31		DB

344. This case may be resolved as the fifth case of right angled spherical triangles, Art. 336, by converting the angles into sides, then finding the angles as in the last problem, where the angles in the converted triangle will be the sides required in this.

Having shewn how to solve all the cases in right and oblique angled spherical triangles, we proceed to shew the extensive use of the globes in the solution of a few of the principal astronomical problems, according to Dr. Flamsted's doctrine of the sphere; and as we do not know these have ever yet been applied to the globes, hope the reader will think them both entertaining and useful.

THE USE OF THE GLOBES IN THE SOLUTION OF SPHERICAL PROBLEMS.

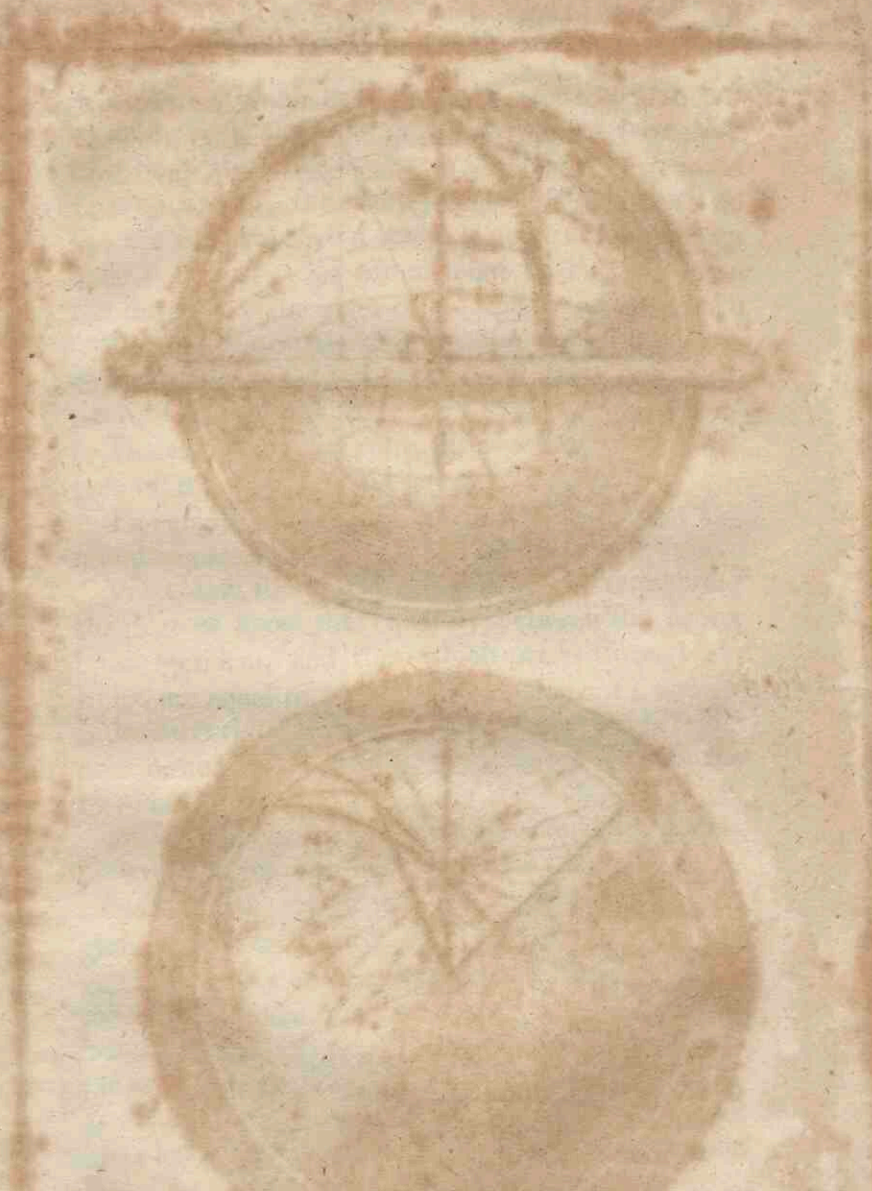
PROBLEM LXXVII. *Given, the sun's place in the ecliptic in ♉ 12° 15′. The inclination of the planes of the equator and ecliptic, 23° 29′.*

To find the sun's right ascension from the first point of Aries, the sun's distance from the north pole of the world, and the angle, which the meridian, passing through the sun at that place, makes with the ecliptic.

345. Fig. 34, The circular space marked ♋, ♎, ♑, ♈, represents the ecliptic, e its pole, P the north pole of the world, elevated 66½ degrees above the first point of ♋. The eye is supposed to be placed directly over the point e, when the reader compares this figure with the globe.

Make a mark ☉, at 12° 15′ in Taurus, to represent the sun's place in the ecliptic, and turn the globe till that meridian which passes through ♎ intersects the point ☉; it will then represent the sun's meridian at that time.

The globe being thus rectified, we have between the sun's proper meridian P ☉, and the solstitial colure ♋ P ♑, here represented by the strong brass



 fronting p. 214.

Fig. 33.

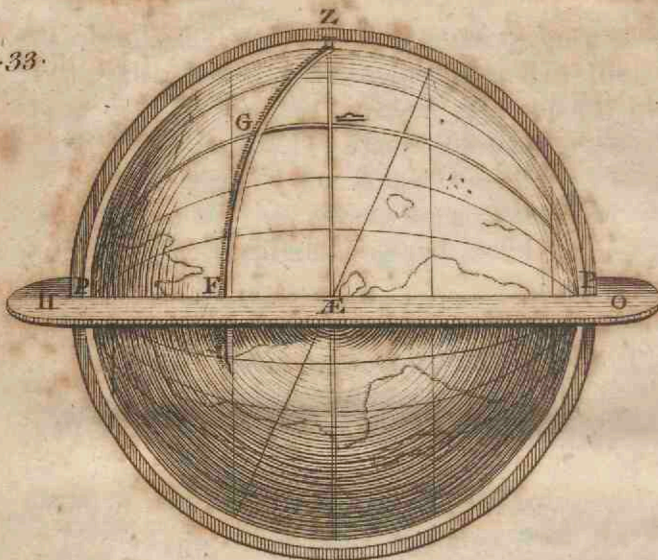
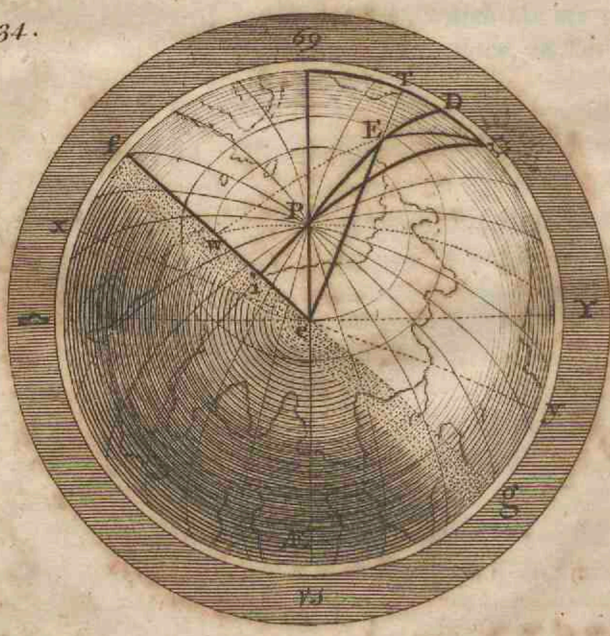


Fig. 34.



Goodnight sculp

meridian, with the arch ⊙ ♋, a spherical triangle ⊙ ♋ P, right angled at ♋, in which we have the following data. See fig. 34.

♋ ⊙ 47° 45′, the complement of ♈ ⊙, which is the sun's distance from the first point of Aries.

♋ P 66° 31′, the complement of P e, 23° 29′, the distance of the poles of the equator and ecliptic.

To find the angle ♋ P ⊙, the complement of ⊙ P ♈, the sun's right ascension from the first point of Aries, Art. 202.

The side P ⊙, the sun's distance from the north pole of the world. And

The angle ♋ ⊙ P, which is the angle that the meridian passing by the sun makes with the ecliptic.

We obtain the measure of the first, by numbering the degrees upon the equator, between the strong brass meridian, and that which passes through ♎, which are equal to 50° 12′, its complement; 39° 48′ is the sun's right ascension, which is that angle at the pole formed by the proper meridian ⊙ P with the meridian ♈ P.

Note. This arch of the equator could not be represented in fig. 34, it being under the broad paper circle; but the reader will see it plainly when the globe is thus rectified.

The quantity of the second postulatum, which is the sun's distance from the nearest pole, is found by inspection, 74° 27′ upon the arch P ⊙ of that meridian passing through ♎, its complement P i, equal to 15° 33′, is the distance of the north pole from the edge of the illuminated disc, represented upon the globe, as in fig. 34, by the semicircle f e g, the black line f e being the quadrant of altitude, and the other dotted half e g being supposed; or, if the reader pleases, he may represent it with a string. This complement P i is, by Dr Flamsted, called the reflection, and is ever equal to the sun's declination.

Lastly, the measure of the angle ♋ ⊙ P, is obtained by screwing the quadrant to e the pole and zenith point of the ecliptic, and counting 90 degrees from ⊙ to f; thither bring its lower end, then will the arch ⊙ i be a quadrant also; and the quantity 72° 10′, counted from f to i, upon the quadrant of altitude, is the measure of the required angle ♋ ⊙ P, formed by the meridian i P ⊙ with the ecliptic ⊙ ♋ ♎.

PROBLEM LXXVIII. *Given, the sun's place in the ecliptic,* ♉ 12° 15′, *the reflection or declination* 15° 33′, *and latitude of the place, suppose London,* 51° 32′.

To find the time of the sun's rising and setting; the length of the day and night; the amplitude of the rising-sun from the east, and of the setting-sun from the west; and that of the path of our vertex in the edge of the illuminated disc.

346. Fig. 35. Elevate P, the pole of the globe, to 15° 33′, the sun's declination, above the plane of B d G i, the circle of illumination: count the same quantity from Æ the equator to ⊙, at which point fix the quadrant of altitude; this point will represent the sun's place; make a mark upon the globe on that meridian which passes through ♎ at 51° 32′ the given latitude; this will express a point in the path of the vertex of London: bring this point to the edge of the disc at B, and set the lower end of

the quadrant thereto: B is that point in the disc from which the sun is seen to rise, or where the vertex of London in its diurnal motion from west to east, passes out of the obscure into the enlightened part of the disc; i P d is the sun's proper meridian, which is represented in this by the strong brass meridian. O is the place at which the vertex of London arrives at noon, being 51° 32′ from Æ the equator at O, and G the place in the disc, from which the sun is seen to set, or where the vertex passes out of the illuminated into the obscure part of the disc. B O G is the diurnal, and G—B, on the other side of the disc, (not here represented, but to be seen upon the globe) is the nocturnal part of the path of London.

If you bring the mark on that meridian which passes through ♎ to the point G, and the quadrant of altitude to the same point, it will be plain that we shall have two triangles formed on each side of i P ☉, the sun's proper meridian, viz. ☉ P B, B i P, on the oriental or ascending side, and ☉ P G, i P G, on the occidental or descending side.

In either of these four triangles there are sufficient data to find what is required in this problem. In the triangles ☉ P B, ☉ P G, are given, ☉ P in both, the sun's distance from the pole, P B, equal to P G, the distance of the vertex from the pole, which is always equal to the complement of the latitude, with the sides ☉ B, ☉ G, each equal to 90 degrees.

To find the angle P B ☉, or P G ☉, the sun's amplitude from the north, when rising or setting; and the angle ☉ P B, or ☉ P G, the time before noon. But as the two last mentioned angles are obtuse, we chuse to resolve this problem by one of the two lesser triangles P B I, P G I, each of them being right angled at i, in which are given, P i, the reflection, 15° 33′, equal to the declination, B P, equal to P G, 38° 28′, the distance of the pole from the vertex.

To find the angle P B i, or P G i, the complement of ⊙ B i, or ⊙ G i, the sun's amplitude at rising or setting from the east or west, and the angle i P B, equal to the angle i P G, which are formed between the sun's proper meridian, and that which passes through the vertex at sun-rising or setting: this changed into time, expresses the time from midnight, of sun-rising and setting. The side B i is called the amplitude of the path of London in the edge of the disc, and these are obtained from the globe as follows:

The measure of the angle B P i is obtained by inspection, reckoning from ♎ upon the equator to the strong brass meridian, which is 96° 31′: if reduced to time, it is 4 h. 38 min. in the morning, at which time the sun rises at London, when he is in ♉ 12° 15′, and consequently sets at 7 h. 22 min. afternoon. See Art. 249.

The quantity 35° 38′ of the required side B i, is obtained by inspection between B and i, upon the edge of the disc.

The measure of the angle P B i may be attained as follows: every thing else remaining as before, bring the graduated edge of the moveable meridian to the first point of ♈ on the ecliptic; then count the complement 54° 22′ of the side B i, from i to x, where make a mark; and count the complement of B P, 51° 32′ from P to y, upon the moveable meridian, where make another mark; remove the quadrant of altitude, and apply it between these two marks, and the quantity 25° 31′ is the measure of the angle P B i, Art. 327. This is the sun's amplitude from the east, or N. E. 3° 1′ easterly.

PROBLEM LXXIX. *Given, the latitude of the place 51° 32′, or rather its complement 38° 28′, which is the distance of the path of the vertex from the pole, and the sun's distance from the pole, 74° 27′, which is the complement of his declination 15° 33′.*

To find the sun's distance from the vertex at the hour of six, and his amplitude at that time.

347. Fig. 35. Elevate P, the pole of the globe, to 15° 53′, the declination; bring the moveable meridian to that which passes through London; slide the artificial horizon to 51° 32′, the latitude of the place, and turn the globe till the sixth hour upon the equator comes under the graduated side of the strong brass meridian; then the moveable meridian, together with that which passes through ♎, will represent the six o'clock hour-circle F K P A g; fix the quadrant of altitude to 15° 33′, at the point ⊙, counted from Æ the equator; turn the quadrant to the point K, which represents the center of the artificial horizon, and the proper triangles will be formed.

In the right angled spherical triangles A P ⊙, K P ⊙, right angled at P, are given P K, equal to P A, 38° 28′, the distance of the vertex from the pole, ⊙ P, the path's distance from the pole 74° 27′. To find ⊙ K, or ⊙ A, the sun's distance from the vertex at the hour of six, and either of the angles, ⊙ A P, or ⊙ K P, the sun's azimuth from the north at the same time.

It is plain that P ⊙, being the sun's proper meridian, F P g at right angles to it, must be the hour-circle of six in the morning and evening, and that the sun rises, when the vertex B comes in the western edge of the sun's enlightened disc. Therefore it must be at K, at six o'clock in the morning; at noon the vertex will be at O, upon O P, the sun's proper meridian; and at six in the evening it will be at A, upon the six o'clock hour-circle again; and when the vertex arrives at G, upon the eastern edge of the disc, the sun will be seen to set westward of the vertex.

The required side ⊙ K, which is the sun's distance from the vertex, is found by counting the quantity 77° 53′ upon the quadrant, from ⊙ to K; and the angle ⊙ K P, 80° 11′; the sun's azimuth from the north may be measured by producing the side K ⊙, to 90 degrees from K to m, (Art. 327.) the side K P being already produced on the other side of the strong brass meridian, K P is known to be 38° 28′; therefore count its complement 51° 32′, from P to n, upon that meridian which passes through ♎, and there make a mark; now remove the quadrant of altitude to cut the opposite point of the horizon to that at which it stood before, and count thereon from ⊙ downwards 12° 07′ to m, where make another mark; then an arch of a great circle applied to these two marks will give 80° 11′, the sun's azimuth from the north.

Note. A flexible semicircle of position, if applied with the quadrant of altitude, will be found useful in this and many other cases.

PROBLEM LXXX. *To find the sun's distance from the vertex when due east or west, and the hour, or time from noon, when he shall be in either of these points.*

348. Fig. 35. The north pole of the globe being elevated to the sun's declination, as in the last problem, and the quadrant fixed at ☉ as before, the moveable meridian placed on that of London, and the center of the artificial horizon set to the same point; turn the globe so that the graduated edge of the quadrant may lie upon the east and west points of the artificial horizon, and the triangle ☉ K P will be formed; in which is given ☉ P, the sun's distance from the pole 74° 27′; P K the distance of the path from the pole 38° 21′; ☉ K, the sun's distance from the vertex, when due east and west, may be found by inspection, counting from ☉ to K upon the quadrant, 70° 0′: the measure of the angle ☉ P K is also obtained upon the equator, counting from that point where it is crossed by the quadrant of altitude, to its intersection with the graduated side of the strong brass meridian, 77° 53′, in time 5 h. 9 min. from noon, which is 51 min. past six in the morning; or at 9 min. past five in the afternoon, when the sun is due east or west.

The sun's distance 70° 0′ from the vertex as found above, when due east or west subtracted from 90 degrees, leaves 20 degrees, which is its altitude above the horizon at either of these times, for ☉ v, ☉ w are quadrants, from which if we take ☉ K in the first, or ☉ A in the second, it is

K v, in one, and A w in the other, equal to the sun's height.

PROBLEM LXXXI. *Given the hour from noon, viz.* 8 *in the morning, which is* 4 *hours from noon, and the sun's distance from the pole,* 74° 27′.

To find his distance from the vertex.

349. Fig. 35. Elevate P the pole of the globe to the sun's declination, 15° 33′, set the moveable meridian to the vertex of London, and slide the center of the artificial horizon to that point at K, and turn the globe, until the eighth hour-circle marked upon the equator comes under the graduated side of the strong brass meridian; the quadrant of altitude being fixed at the point ⊙ as before, turn it to the point K, and the triangle ⊙ P K will be formed; in which is given the angle K P ⊙, four hours from noon, P K, 38° 28′ the distance of the path from the pole; ⊙ K, the sun's distance from the vertex will then be found, by inspection on the quadrant, counting from ⊙ to K 59° 20′.

PROBLEM LXXXII. *Given the sun's distance from the pole* 74° 27′, *the latitude of the place* 51° 32′, *and the sun's distance from the vertex by observation,* 46° 11′.

To find the time of the day when that observation was made, and the azimuth upon which the sun was at that time.

350. Fig. 35. Elevate P the pole of the globe, to 15° 33′, the complement of the sun's distance from the pole; bring the moveable meridian to the vertex

of London, and slide the center of the artificial horizon to that point: then screw the quadrant to ☉ the zenith of the illuminated disc, and bring its graduated edge to London; and move the globe and quadrant, that the vertex may cut the quadrant at 46° 11′, the observed distance counted from ☉ to K; and an oblique angled triangle ☉ K P will be formed upon the globe, in which we have three sides given, ☉ P, 74° 27′ the sun's distance from the pole, ☉ K his observed distance from the vertex 46° 11′ in the morning, and K P 38° 28′ the distance of the pole from the vertex: to find the angle K P ☉, count the quantity contained upon the equator, between the moveable and strong brass meridians, which will be found 36° 23′, or 2 h. 25 min. in time from noon, which is 35 minutes past 9 o'clock in the morning.

The angle P K ☉ may be measured by producing the arches which include the angle to the distance of 90 degrees from the angular point as in Art. 332, or by Art. 339, and it will be found 127° 40′, or 11 points of the compass from the north, reckoned round by the east, or S E b E, 3° 35′ southerly.

If the observation had been made in the afternoon, at the same height or distance from the vertex, the answers would have been the same, but in a contrary direction.

By this problem we may regulate our clocks at any time of the day, without staying till the sun comes to the meridian; if the sun's altitude be taken by a large quadrant, and you note the time by the clock when the observation was taken, and the true time answering thereto be found as above, or by calculation, the difference between this and the time pointed out by the clock at the instant of observation will shew how much the clock is before or behind the solar apparent time.

PROBLEM LXXXIII. *Given, the latitude of the place* 51° 32′, *the sun's place* ♉ 12° 15′, *the sun's right ascension,* 39° 48′, *at one o'clock afternoon, being the time when an observation was made:*

To find what point of the ecliptic culminates upon the meridian, which is the highest point of it, or the 90*th degree from the points wherein it intersects the horizon, and consequently those points themselves; the distance of the nonagesimal and mid-heaven points from the vertex; and the angle made by the vertical circle passing through the sun at that time with the ecliptic.*

351. Fig. 34. Elevate P the pole of the globe to 66½ degrees, count the same quantity from Æ the equator to e, there fix the quadrant of altitude; this point e, will then be the pole of the broad paper circle marked ♈ ♋ ♎ ♑, which now represents the ecliptic, in which at ☉ put a mark, at ♉ 12° 15′, for the place of the sun; bring the graduated edge of the moveable meridian first to the vertex of the given place, in this example London, and bring the center of the artificial horizon thereto; next set it to the point marked ☉, and the horary index to that XIIth hour upon the equator which is most elevated, and turn the globe until the given time one hour from noon comes under the horary index. Then set the graduated edge of the quadrant of altitude to the vertex at E, and the globe will be rectified for a solution of this problem,

in which we have two spherical triangles, P ♋ D, and e P E.

E, is that point in the path on which the vertex is at one o'clock afternoon ; D, that point of the ecliptic which then culminates upon the meridian E ☉ ♋, the angle made by E ☉ the vertical circle then passing through the sun with the ecliptic; the point T in the ecliptic, which is cut by the quadrant of altitude passing through E, is evidently the nearest point to the vertex, or the highest or nonagesimal point of it. E T is the distance of the point T from the vertex E, and E D the distance of D from the vertex, which is the point then culminating upon the meridian.

In the triangle D ♋ P, is given the angle ♋ P D, the complement of ♈ P D, which is the right ascension of the mid-heaven, the sun's given right ascension 39° 48′, agreeable to the sun's place ♉ 12° 15′, at noon, to which the addition of 15° for one hour after noon, as we did above in rectifying the globe, makes the angle ♈ P D 54° 48′ the present right ascension of the mid-heaven, and P E D the meridian at that time; P ♋ 66° 31′, and the angle at ♋ right.

I. To find ♋ D, the complement of ♈ D, the longitude of P D the mid-heaven from the first point of ♈, which is obtained on the ecliptic here represented by the broad paper circle between points ♋ and D, 32° 54′, or between ♈ and D, 57° 6′, the longitude itself, which is 27 deg. 6 min. in Taurus. D is that point of the ecliptic which culminates upon the meridian at that time; whence we may readily find what points of the ecliptic rise and set at that time.

The quantity 70° 27′ contained between P the pole of the globe, and D upon the moveable meridian, is the distance of D the mid-heaven point from the pole; if we deduct P E 38.28, or count the quantity between D and E, we shall have 31° 59′, the distance of the point D in the ecliptic which now culminates on the meridian from the vertex E, its complement to 90 degrees being 58° 1′ is the height of the ecliptic at this time, or the inclination of the ecliptic to the horizon of the place.

II. To find ♋ T, the complement of ♈ T, which is the longitude of the nonagesimal, and T E its distance from the vertex.

In the oblique angled spherical triangle P e E, are given P e 23° 29′, the distance of the poles of the equator and ecliptic, P E, 38° 28′ the co-latitude with the included angle e P E 144° 48′, the complement of 35° 12′ the distance of the mid-heaven from the first point of ♋ to 180 degrees. The measure of this angle is obtained upon the equator between the strong brass, and the moveable meridians.

To find the angle P e E, as it is included between ♋ e, the strong brass meridian, and e T the quadrant; we have its measure 24° 44′ upon the arch ♋ T of the ecliptic, its complement 65° 16′ is ♈ T, the longitude of the nonagesimal from the first point of Aries, or ♊ 5° 16′ its distance E T from the vertex E, is gained on the quadrant of altitude 31° 2′, the complement of which 58° 58′ is the altitude of the ecliptic above the horizon at this time; or it is the angle which the planes of the ecliptic and horizon make with each other; as T is the highest point of the ecliptic at this time, and its longitude in ♊ 5° 16′, three signs or 90 degrees counted on the broad paper circle from T towards x will give ♍ 5° 16′ for that point of the ecliptic which is then rising, and the same quantity counted from T towards y will fall upon ♓ 5° 16′ which point is then setting.

III. To find the angle E ⊙ T, being that which a vertical circle E ⊙ passing through the sun at that time makes with the ecliptic; this is called the parallactic angle.

To represent this angle upon the globe, it is necessary to have a flexible slip of brass, or a slip of parchment about the breadth of the quadrant of altitude, with the divisions inscribed on it with a pen; if this slip be applied to the point ⊙, and its graduated edge laid over the vertex E, and extended to the quadrant of altitude first removed to x 90 degrees from ⊙, it will intersect the quadrant at w; the quantity upon the quadrant, from x to w, will be 56° 29′, the measure of the parallactic angle E ⊙ T. The result of this problem is as follows:

That point of the ecliptic which culminates on the meridian is in ♉ 27° 6′, its distance from the vertex 31° 59′, the highest or nonagesimal point of the ecliptic, ♊ 5° 16′, its distance from the vertex 31° 2′, the rising point of the ecliptic ♍ 5° 16′, its setting point ♓ 5° 16′, the distance of the nonagesimal from the mid-heaven 8° 10′, and the parallactic angle at this time 56° 59′.

PROBLEM LXXXIV. *Given, the latitude of the place, right ascension and declination of any point of the ecliptic, or of a fixed star:*

To find its rising or setting amplitude, its ascensional difference, and thence its oblique ascension.

352. Fig. 36. Elevate P, the pole of the globe to 51° 32′, the latitude of London; then the diurnal parallel of the first point of Cancer will be represented by ♋ F, the tropic of that name, marked ♋ e F, in fig. 36, bring the first point of ♋ on the ecliptic line to the graduated edge of the strong brass meridian, and e will be the point where it rises; to this point bring the graduated edge of the moveable meridian, represented in the figure by P e g p, then a e, upon the horizon at H O, or the angle a Z e, from the angular point Z m, the zenith will be its rising amplitude, from the east at Aries, towards the north point of the horizon at o, and a g, determined by the moveable meridian, which now represents a circle of right ascension passing through the points e and g, and the horizon its ascensional difference, which subtracted from its right, leaves its oblique ascension.

The ascensional difference is the difference between that point of the equator, which culminates upon the meridian, with the first point of Cancer, and that other point of the equator which rises with it above the horizon; it is here subtracted, to find the oblique ascension; because that point of the equator which rises with the first point of Cancer, comes to the horizon before the point of its right ascension, or that point with which it culminates upon the meridian.

In the triangle a g e, we have g e, the northern declination of the point e, in the diurnal parallel of the first point of Cancer, equal to 23° 29′, the angle g a e, which is the inclination of the planes of Æ Q the equator, and H O the horizon, with the angle at g right. Whence upon the horizon we obtain between a and e, 39° 50′, the rising amplitude of the first point of ♋, which is N E b E, and 5° 20′ more. Upon the equator, from a to g, we find 33° 9′, the ascensional difference of the first point of Cancer: which subtracted from 90 deg. the right ascension of that point, leaves 56° 51′, its oblique ascension.

Every thing else upon the globe remaining the same, if we bring the moveable meridian to the point n, where the tropic of Capricorn intersects the horizon, we shall have another triangle a b n, equal to the former, wherein the first point of Capricorn has the same amplitude 23° 29′ from a, in the east, to n, towards H, the south part of the horizon, that the former triangle had towards the north; and this added to the right ascension of the first point of Capricorn, 270° 00′, gives its oblique ascension 303° 09′, because that point of the equator which rises with the first point of Capricorn comes to the horizon after the point of its right ascension, or that with which it culminates upon the meridian.

353. *Note.* Every star which rises with any point of the ecliptic, has the same oblique ascension with that point.

The star marked v, in the leg of the constellation

Bootes, of the fourth magnitude, which is represented in fig. 36. at the point ♓, having its north declination of 17° 21′, its ascensional difference a f, rises above the horizon with the same point of the equator with which e, in the diurnal parallel of the first point of Cancer, rises. So that having its right ascension 204°, and declination 17° 21′, its ascensional difference and oblique ascension may be found in the triangle a f ♓, in the same manner in which the former were found in the triangle a g e.

As the ascensional difference is subtracted from the right ascension to find the oblique ascension, if it be added to the right ascension it will give the oblique descension. For that point of the equator which sets with the diurnal parallel of the first point of Cancer, comes to the horizon before the point of its right ascension, or that with which it culminates upon the meridian. Hence we have another method of finding the length of the day at London, or elsewhere, when the sun is in the first point of Cancer, or any other parallel of his declination, viz.

354. Subtract the sun's ascensional difference in time from six in the morning, the residue is the time of his rising; add it to six in the evening, and it gives the time of his setting; then doubling the first, you obtain the length of the night, and the double of the last will be the length of the day. And after this manner all these particulars may be found to every intermediate point of the ecliptic in all latitudes.

As the rising and setting of some of the principal fixed stars are mentioned by ancient writers, as criteria by which to judge of the commencement of seasons, and the beginning of times set apart for religion, husbandry, politics, &c. we have judged it necessary to add the following problems, as a farther elucidation of the two former, Art. 302, and 303.

Problem LXXXV. *Given, the latitude of the place, the points of the ecliptic with which a star rises or sets, and the altitude of the nonagesimal, when those points are upon the horizon:*

To find in what points of the ecliptic the sun must be to make the star when rising or setting appear just free from the solar rays; and thence the times of its heliacal rising and setting.

355. Fig. 36. Elevate P, the pole of the globe, to the latitude of the place, and fix the quadrant of altitude in the zenith at Z, and H O will represent the horizon. Turn the globe until the given star just appears at ♓ in the edge of the horizon, and a will be that point of the ecliptic in which the sun must be when the star rises and sets with it: Let us suppose the star at ♓ to be of the first magnitude, which requires that the sun should be depressed 12 degrees below the horizon, that the star may appear free from the solar rays: having noted the point a, on the ecliptic, move the quadrant until the 12th degree below the horizon intersects the ecliptic at s, then Z s will represent a vertical circle, in which the sun at s is depressed 12 degrees.

So in the triangle a C S, right angled at C, we have the sides C S, 12 degrees, the requisite depression of the sun below the horizon, to free the star from his rays, or that point of the ecliptic at S, to make the star at ♓ first heliacally visible when it rises, or from which we may see upon the other side of the globe when it sets heliacally.

The angle S a C is the altitude of the nonagesimal, or inclination of the planes of the ecliptic and horizon; and the angle at C right, being formed by the intersection of a vertical circle with the horizon: the measure of the angle S a C, is obtained by inspection on the brass meridian from O to ♑, the point in which the tropic of Capricorn cuts that circle; the side a S, being an arch of the ecliptic, through which the sun passes, from the time the star at v rises with him to its heliacal rising, or an arch of the same quantity on the other side of the globe, through which the sun must have passed from the time when the star set heliacally, to its setting with the sun, which, as in the former case, added to the point of the ecliptic, in which the sun is when the star rises with him, gives the point he is in at its heliacal rising; and in the latter case subtracted from that point of the ecliptic the sun is in when the star sets with him, leaves the point he is in at the same star's heliacal setting.

Thus having found the points of the ecliptic in which the sun must be when any star rises or sets heliacally, against those points in the kalendar, on the horizon, you obtain the month and day.

As the distances of the fixed stars from one another have been found the same in all ages, it is probable they have no real motion of precession, but only an apparent one, caused by the retrocession of the equinoctial points, which are found to recede from their ancient stations at the rate of 50 seconds every year; this alters their longitude, but their latitude does not vary: hence their places being once determined to a known year, their longitudes may be ascertained for any time past or to come, by the sole subtraction or addition of so many times 50 seconds, as there are years between that to which the given star is rectified, and that to which it is required; or knowing the quantity of precession from any former period, the distance thereof in time may be obtained, by reducing it into seconds, and dividing the result by 50, the quotient will give the number of years, as in the following examples:

EXAMPLE I.

Given, 1908 years. To find the quantity of the precession for that time.

1908 years.
Multiply by 50 seconds.

60) 95400

60) 1590

Answer .... 26° 30′ precession in 1908 years.

EXAMPLE II.

Given, 26° 30′, the quantity of the precession, to find the time.

	26° 30′	
Multiply by	60	
	1590	minutes.
Multiply by	60	
Divide by 50)	95400	seconds.
Answer . . .	1908	years.

The regular change in the precession of the fixed stars, or rather the constant retrogression of the equinoctial points, seems to cause an irregular variation in their right ascensions and declinations, more or less, according to their distances from the pole of the ecliptic. Whence it may not be improper to shew how these may be found, as the cosmical, achronical, and heliacal risings and settings of the fixed stars, found by the preceding problems, have respect only to the present age: and the following problem, with which I shall conclude this treatise, will shew the reader how to determine the ancient place of any star agreeable to the time of ancient authors, if their authority may be depended on.

PROBLEM LXXXVI. *Given, the latitude and ancient longitude of a fixed star:*
To find its right ascension and declination.

Elevate the celestial globe to $66\frac{1}{2}$ degrees, bring the pole of the ecliptic into the zenith, and there fix the quadrant of altitude; apply its graduated edge to the given star, and it will cut its present longitude, either on the ecliptic or broad paper circle, which in this position of the globe coincide with each other: make a mark on the quadrant, at the latitude of the given star, and remove it to its ancient longitude, as found above; then bring the graduated edge of the moveable meridian to the mark just made upon the quadrant of altitude, and set the center of the artificial sun to that point which will then represent the ancient place of the given star. That point of the moveable meridian, upon which the center of the artificial sun was placed, is its ancient declination; and that point of the equator, cut by its graduated edge, is its ancient right ascension.

The globe being thus rectified to the place and precession of any particular star, as given us by ancient authors, the times of the year when such star rose or set, either cosmically, achronically, or heliacally, may be thus obtained by the preceding problems, agreeable to the period of the author under consideration.

A TABLE OF RETROCESSION AND AUTUMNAL EQUINOXES.

	Retrocession.			Autumnal Equinoxes.		
Years.	D.	H.	M.	Days.	H.	M.
6000	45	20	0	2191454	4	0
5000	38	4	40	1826211	19	20
4000	30	13	20	1460969	10	40
3000	22	22	0	1095727	2	0
2000	15	6	40	730484	17	20
1000	7	15	20	365242	8	40
900	6	21	0	328718	3	0
800	6	2	40	292193	21	20
700	5	8	20	255669	15	40
600	4	14	0	219145	10	0
500	3	19	40	182621	4	20
400	3	1	20	146096	22	40
300	2	7	0	109572	17	0
200	1	12	40	73048	11	20
100	0	18	20	36524	5	40
90	0	16	30	32871	19	30
80	0	14	40	29219	9	20
70	0	12	50	25566	23	10
60	0	11	0	21914	13	0
50	0	9	10	18262	2	50
40	0	7	20	14609	16	40
30	0	5	30	10957	6	30
20	0	3	40	7304	20	20
10	0	1	50	3652	10	10
9	0	1	39	3287	4	21
8	0	1	28	2921	22	32
7	0	1	17	2556	16	43
6	0	1	6	2191	10	54
5	0	0	55	1826	5	5
4	0	0	44	1460	23	16
3	0	0	33	1095	17	27
2	0	0	22	730	11	38
1	0	0	11	365	5	49

A TABLE OF MONTHS.

Literal Characters.	Days in each Month.		Days à Kal. January.
A	31	January	31
D	28	February	59
D	31	March	90
G	30	April	120
B	31	May	151
E	30	June	181
G	31	July	212
C	31	August	243
F	30	September	273
A	31	October	304
D	30	November	334
F	31	December	365

A TABLE OF WEEK-DAYS.

4	Monday
5	Tuesday
6	Wednesday
0	Thursday
1	Friday
2	Saturday
3	Sunday

A TABLE OF THE HORARY DIFFERENCE IN THE MOTION OF THE FIRST POINT OF ARIES, AT THE TIME OF A VERNAL EQUINOX.

M. H.	S. M.	‴ S.	M. H.	S. M.	‴ S.
1	0	9	31	4	42
2	0	18	32	4	51
3	0	27	33	5	0
4	0	36	34	5	9
5	0	45	35	5	18
6	0	54	36	5	27
7	1	4	37	5	36
8	1	13	38	5	45
9	1	22	39	5	54
10	1	31	40	6	3
11	1	40	41	6	12
12	1	49	42	6	21
13	1	58	43	6	31
14	2	6	44	6	40
15	2	16	45	6	49
16	2	25	46	6	58
17	2	34	47	7	7
18	2	43	48	7	16
19	2	53	49	7	25
20	3	2	50	7	34
21	3	11	51	7	43
22	3	20	52	7	52
23	3	29	53	8	0
24	3	38	54	8	8
25	3	47	55	8	17
26	3	56	56	8	25
27	4	4	57	8	35
28	4	12	58	8	45
29	4	22	59	8	55
30	4	32	60	9	5

A TABLE OF THE DIFFERENCE OF THE PASSAGE OF THE FIRST POINT OF ARIES OVER THE MERIDIAN, FOR EVERY DAY IN THE YEAR.

I.

Days.	January.			February.			March.			Days.
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	5	10	53	2	58	46	1	9	50	
2		6	28		54	42		6	7	1
3		2	4		50	39		2	24	2
4	4	57	40		46	37	0	58	41	3
5		53	16		42	36		54	58	4
6		48	53		38	36		51	16	5
7		44	31		34	36		47	34	6
8		40	9		30	37		43	52	7
9		35	47		26	39		40	11	8
10		31	26		22	42		36	30	9
11		27	6		18	45		32	50	10
12		22	46		14	50		29	10	11
13		18	27		10	55		25	31	12
14		14	9		7	1		21	52	13
15		9	51		3	7		18	13	14
16		5	33	1	59	14		14	34	15
17		1	17		55	22		10	55	16
18	3	57	2		51	32		7	16	17
19		52	47		47	42		3	38	18
20		48	33		43	52	0	0	0	19
21		44	19		40	3	23	56	22	20
22		40	6		36	14		52	44	21
23		35	54		32	26		49	6	22
24		34	43		28	39		45	28	23
25		27	33		24	52		41	50	24
26		23	24		21	6		38	12	25
27		19	15		17	20		34	34	26
28		15	7		13	35		30	56	27
29		11	0					27	18	28
30		6	54					23	40	29
31		2	49					20	2	30

II.

Days.	April.			May.			June.			Days.
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	23	16	24	21	25	12	19	22	28	
2		12	46		21	23		18	22	1
3		9	8		17	33		14	16	2
4		5	29		13	43		10	9	3
5		1	50		9	52		6	2	4
6	22	58	11		6	0		1	55	5
7		54	33		2	8	18	57	48	6
8		50	54	20	58	16		53	40	7
9		47	14		54	23		49	32	8
10		43	35		50	30		45	24	9
11		39	55		46	35		41	15	10
12		36	14		42	40		37	6	11
13		32	33		38	44		32	57	12
14		28	52		34	49		28	48	13
15		25	11		30	51		24	39	14
16		21	30		26	54		20	29	15
17		17	47		22	56		16	20	16
18		14	4		18	58		12	11	17
19		10	21		14	59		8	1	18
20		6	38		11	0		3	51	19
21		2	54		7	0	17	59	42	20
22	21	59	11		2	59		55	33	21
23		55	26	19	58	59		51	23	22
24		51	41		54	58		47	14	23
25		47	55		50	56		43	4	24
26		44	9		46	53		38	55	25
27		40	23		42	50		34	46	26
28		36	36		38	46		30	37	27
29		32	48		34	42		26	29	28
30		29	0		30	38		22	20	29
31					26	33				30

III.

Days.	July.			August.			September.			Days.
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	17	18	11	15	13	26	13	17	22	
2		14	3		9	33		13	45	1
3		9	56		5	41		10	8	2
4		5	48		1	49		6	31	3
5		1	41	14	57	58		2	54	4
6	16	57	34		54	8	12	59	17	5
7		53	28		50	18		55	40	6
8		49	22		46	29		52	4	7
9		45	17		42	40		48	28	8
10		41	12		38	52		44	52	9
11		37	7		35	5		41	16	10
12		33	2		31	18		37	40	11
13		28	58		27	32		34	4	12
14		24	55		23	46		30	29	13
15		20	52		20	1		26	54	14
16		16	49		16	16		23	18	15
17		12	47		12	32		19	43	16
18		8	46		8	48		16	7	17
19		4	45		5	5		12	31	18
20		0	45		1	22		8	56	19
21	15	56	45	13	57	40		5	20	20
22		52	46		53	58		1	44	21
23		48	48		50	16	11	58	8	22
24		44	49		46	35		54	32	23
25		40	51		42	55		50	56	24
26		36	54		39	14		47	20	25
27		32	57		35	35		43	44	26
28		29	2		31	55		40	7	27
29		25	6		28	17		36	30	28
30		21	12		24	38		32	53	29
31		17	18		21	0				30

IV.

Days.	October.			November.			December.			Days.
	H.	M.	S.	H.	M.	S.	H.	M.	S.	
1	11	29	15	9	32	50	7	28	50	
2		25	37		28	55		24	29	1
3		21	59		24	58		20	8	2
4		18	20		21	0		15	47	3
5		14	42		17	2		11	25	4
6		11	3		13	3		7	3	5
7		7	23		9	3		2	40	6
8		3	43		5	2	6	58	17	7
9		0	2		1	0		53	54	8
10	10	56	21	8	56	57		49	30	9
11		52	40		52	53		45	6	10
12		48	58		48	49		40	41	11
13		45	16		44	44		36	15	12
14		41	33		40	38		31	50	13
15		37	50		36	31		27	24	14
16		34	6		32	23		22	58	15
17		30	21		28	14		18	32	16
18		26	36		24	5		14	5	17
19		22	50		19	54		9	39	18
20		19	4		15	44		5	13	19
21		15	17		11	32		0	46	20
22		11	29		7	19	5	56	19	21
23		7	40		3	5		51	52	22
24		3	51	7	58	51		47	25	23
25		0	2		54	36		42	59	24
26	9	56	11		50	20		38	33	25
27		52	20		46	4		34	6	26
28		48	27		41	47		29	40	27
29		44	34		37	29		25	14	28
30		40	41		33	13		20	48	29
31		36	47					16	23	30

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