A TREATISE ON THE New Celeſtial and Terreſtrial GLOBES.

The New
TERRESTRIAL GLOBE,
As Improved and Constructed by GEO: ADAMS
In 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 Phoenomena 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,

Mathematical Inſtrument-Maker to His Majesty.

The THIRD 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.

LONDON:

Printed for and Sold by the Author, at Tycho Brahe's Head, N°. 60, in Fleet-Street.

M. DCC. LXXII.

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 solicite the patronage of Your MAJESTY to the humble labours by which I have endeavoured to improve the instruments of science, and make the

globes

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is now waiting on Your determinations, and may receive benefits or ſuffer evils, as Your influence is extended or withdrawn.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 gives 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

tudes 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.

ADVERTISEMENT.

BEING encouraged to offer to the Public a third edition of my TREATISE ON THE GLOBES, *I thought myself engaged to consider, whether I might not be able, by a few additions, to render it more useful than the former.*

And as some observations on the solar system seemed to be wanting, I have herein endeavoured to supply that defect, by prefixing a short view of it.

I have also added some pertinent problems, and extended the use of the Globes to the solution of all cases in Spherical Trigonometry. which are applied to a variety of astronomical problems; and that these additions might be more instructive and amusing, I have illustrated them by eleven copper plates.

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 phœnomenon 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.

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

ſkill in geometry than is commonly poſſeſſed by beginners, for whoſe uſe the following treatiſe is principally deſigned; tho' 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 the common globes.

That agreement too, which is here pointed out between the celeſtial and terreſtrial ſphere, will be found to open a large field of geographical and aſtronomical knowledge; and will afford both inſtruction and amuſement to every unprejudiced enquirer. 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

By theſe ſteps of ſcience, the mind of man may be raiſed to the contemplation of the divine wiſdom, which has ſo adjuſted the proportions 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 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. 27. for the globes of eighteen inches 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

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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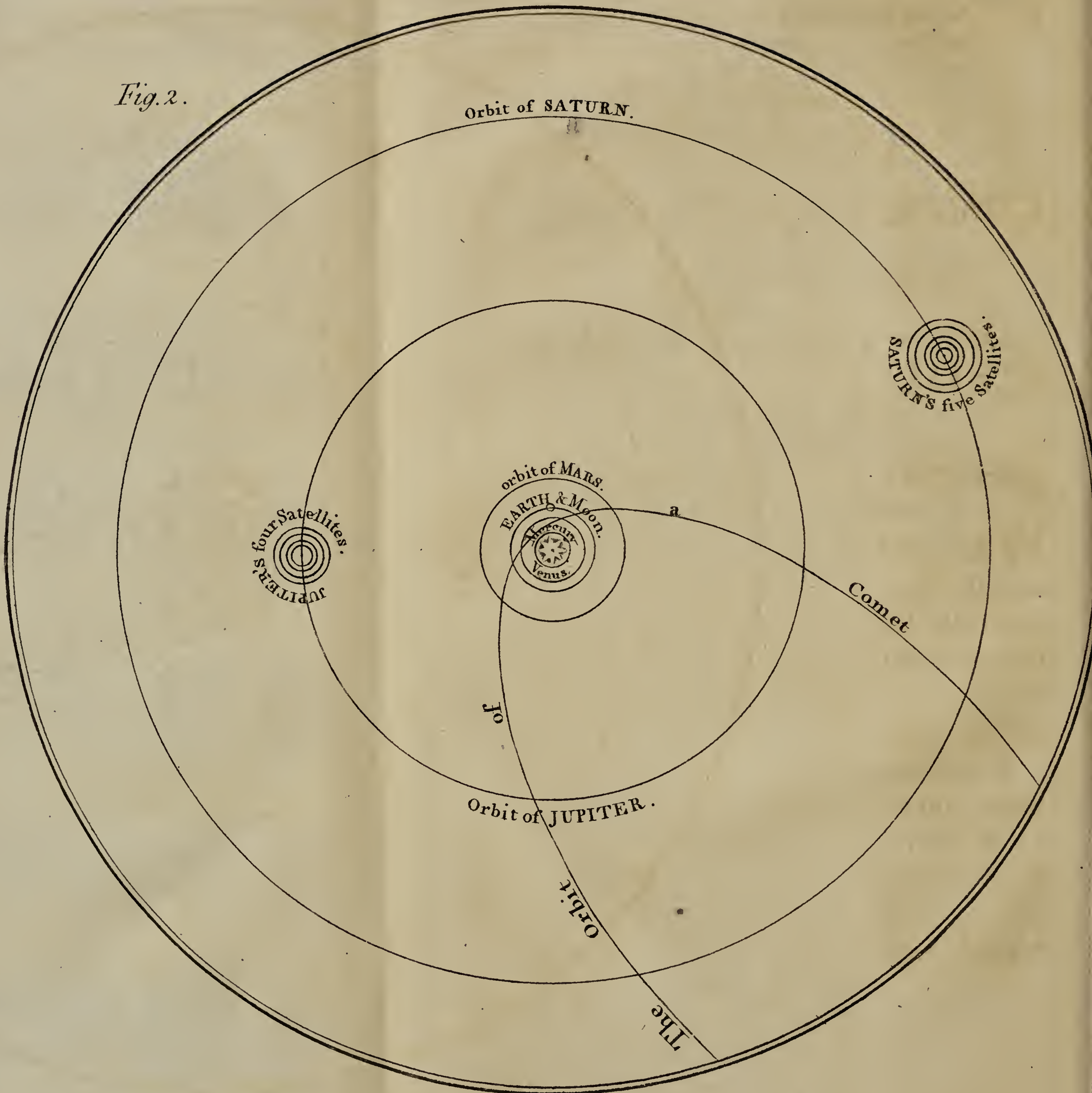
the

A.

The Copernican or

SOLAR SYSTEM.

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 con-

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 center, having a motion round its axis, which is completed in about 25¼ 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 87½ degrees.

3. The ſix primary planets move round the ſun in their reſpective elliptical orbits, from weſt to eaſt, at different diſtances, and in

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 follows:

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 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

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 ABCD 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 EDFB, is meaſured. The inclination of the orbit or Mercury is 6°, 52′, that of Venus 3°, 33′, of Mars 1°, 52′, of Jupiter 1°, 20′, and 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 BD 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 inferior, 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; there-

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 days, 8 hours, according to Bianchini; and the inclination of her axis to the plane of the ecliptic, is 15 degrees.

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 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 degrees. 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; 1. when it is between the earth and the sun, called the inferior conjunction; 2. 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

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 planets 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

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

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 degrees distant from the sun; the inferior planets cannot be in quadrature, as their greatest elongation can never

be

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 degrees, and of Venus 48 degrees.

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,

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 appear 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

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 thro' 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 days, 5 hours, 49 minutes. Besides this annual motion, it turns round its own axis in 24 solar hours; its axis is constantly inclined in an angle of 66½ degrees 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, ABCD the orbit of the earth; in the periphery of which, the center of the earth is carried round the sun, according to the order of the

Fig. 3.

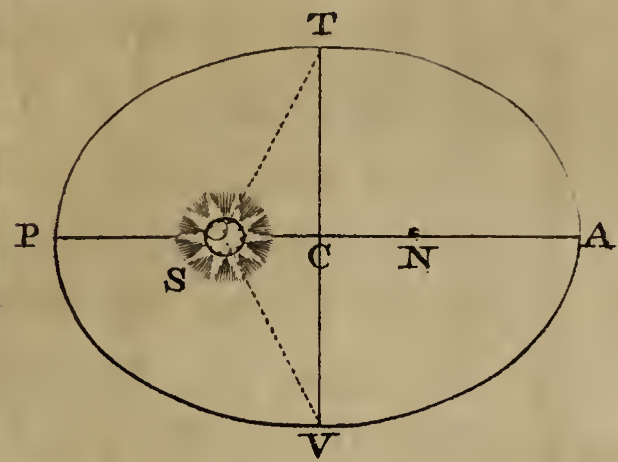
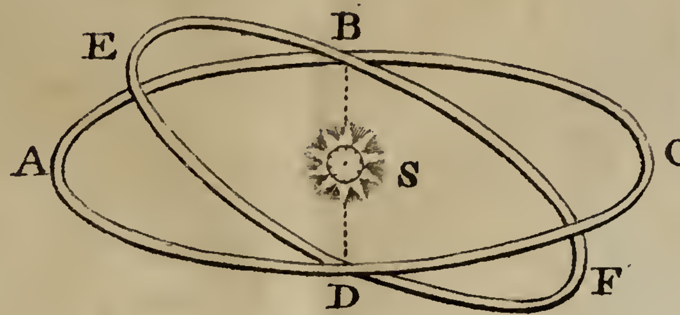


Fig. 4.



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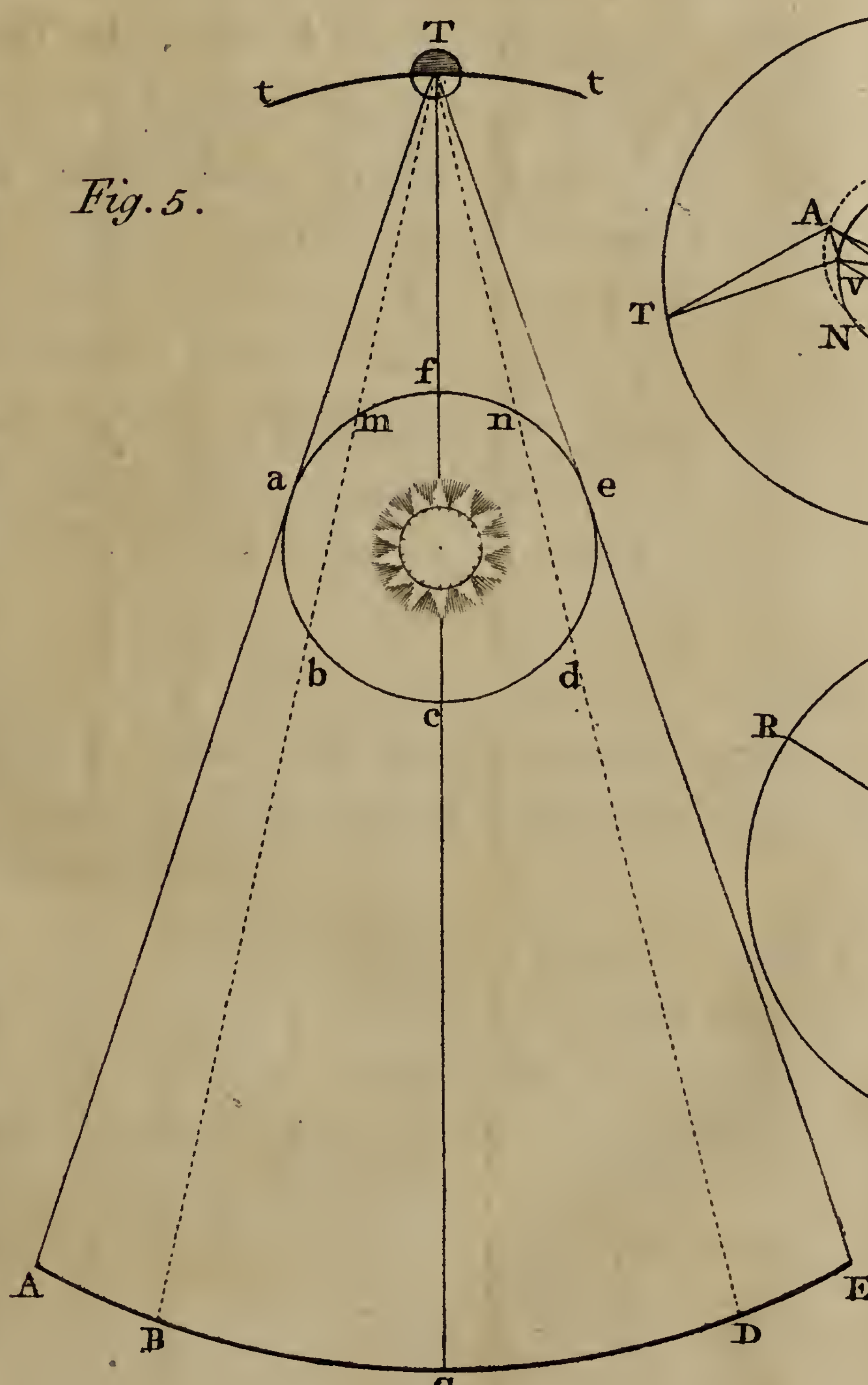
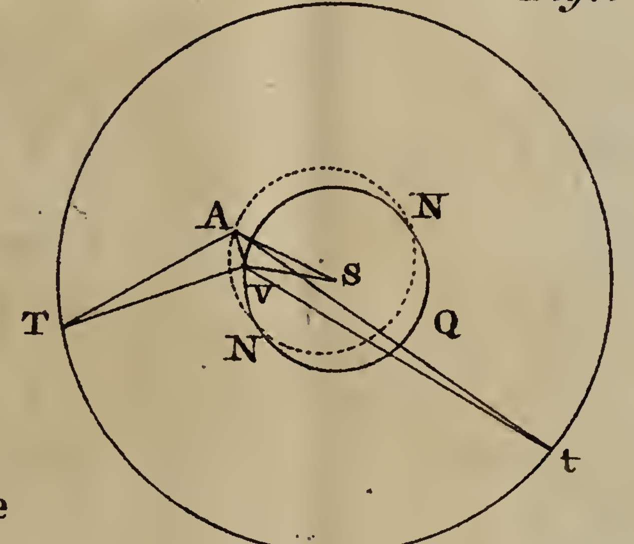


Fig. 6.



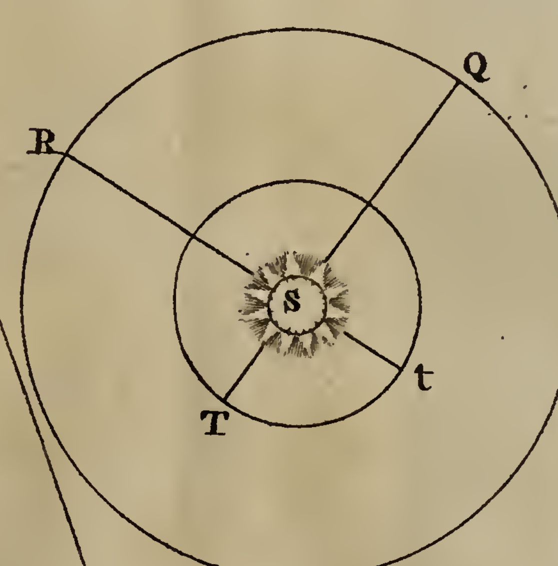
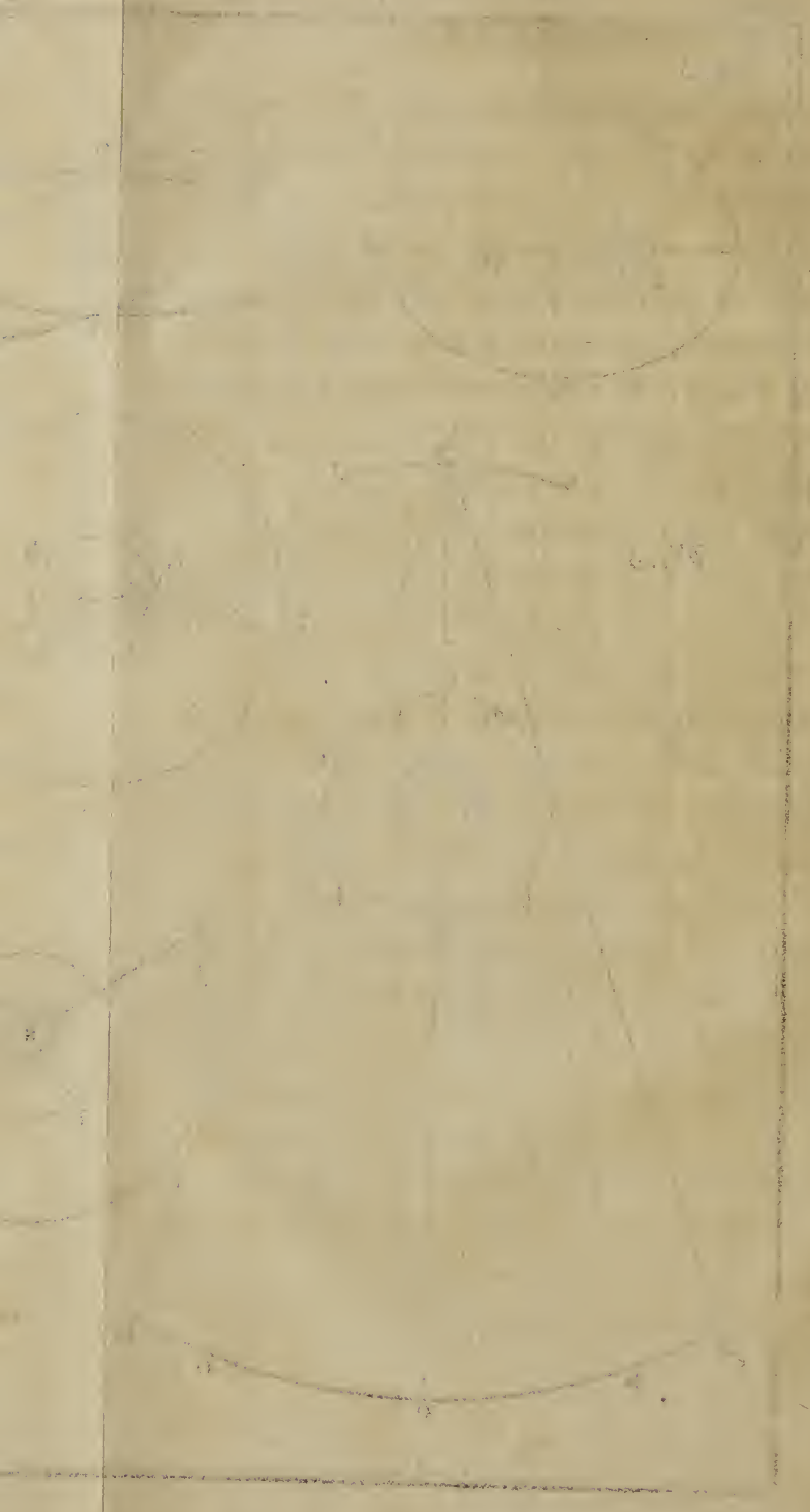


Fig. 7.



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 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

appear in Libra about the 19th of March; at which times of the year the edge of the enlightened hemiſphere is parallel to the ſolſtitial colure; fig. 8. and paſſes thro' 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 throughout the whole diurnal revolution; at which time their inhabitants ſee the ſun longer than 24 hours; 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

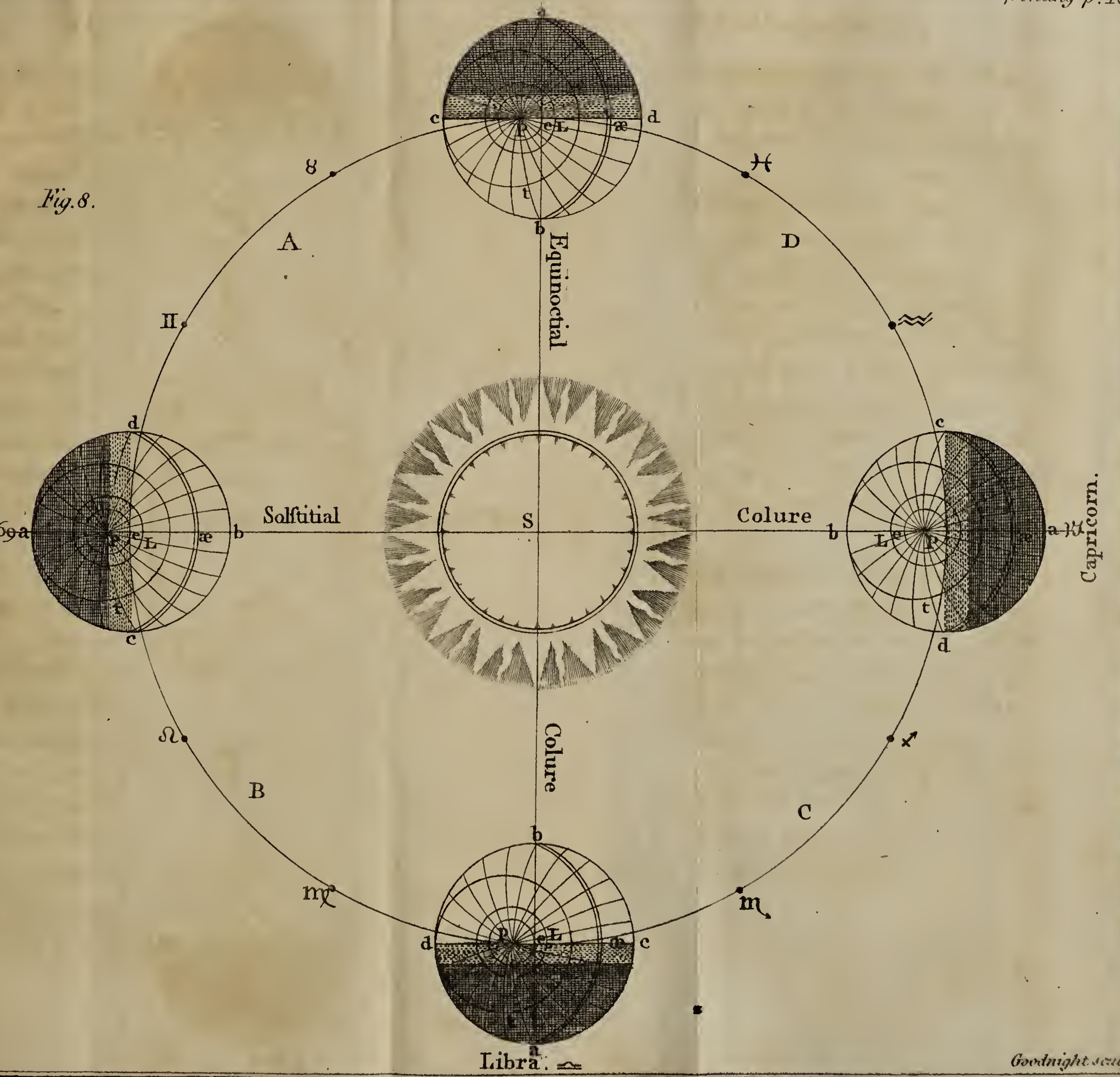
parallel interſects the edge of the diſc; and as the illuminated part of each is much greater than the obſcure part, the days are conſequently at this ſeaſon, of the ſummer ſolſtice, which happens about the 21ſt of June, longer than the nights. While the earth is moving from Libra, through Capricorn 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 exceeded 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

Plate 4. *fronting p. 18.*

Fig. 8.



Goodnight sculp

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 thro' 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. ABCD 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 thro' 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 thro' A to B, the ſun appears to run thro' 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 eliptical orbit A B C D into two unequal parts, (the ſun not being in the center, 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

apparent diameter in winter is 32 min. 47 ſec. in ſummer 31 min. 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 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 min. 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 days 12 hours. 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 days 7 hours. It is not yet known 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 degrees. If we ſuppoſe the diameter of Saturn to be divided into four equal parts, the

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 thro' the ſun, and then the ring becomes inviſible to us.

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 A D G, 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,

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 center at I, the other end A will then mark out the planet's apparent motion in the heavens. So that the arch ABCDEFG, will be that which 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 thro' 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

53. The time of the retrogression of Mars is about 3 months; of Jupiter, 4 months; and of Saturn, 4½ 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.

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

Fig. 9.

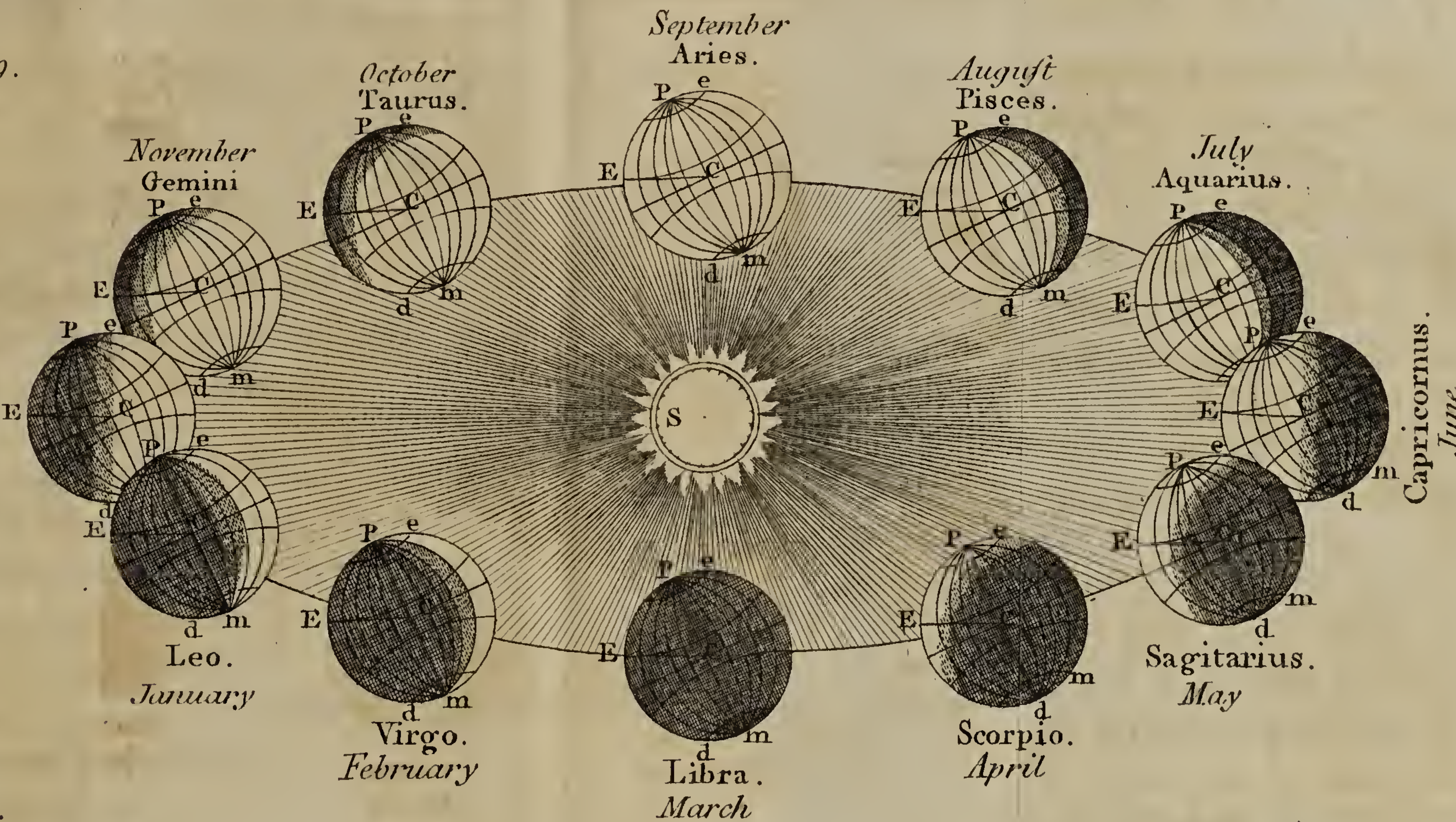


Fig. 10.

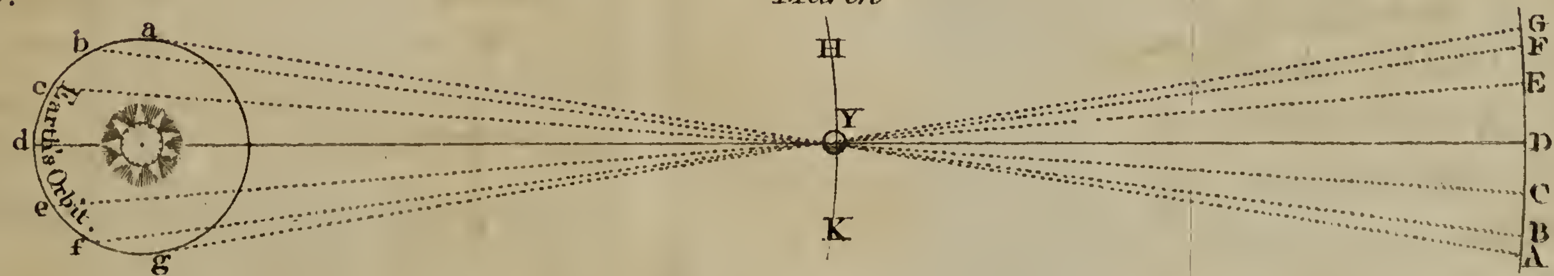
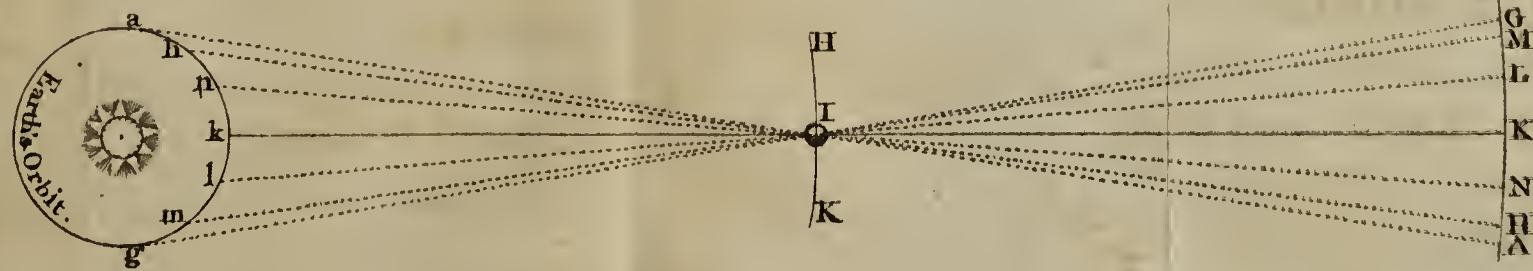


Fig. 11.



their reſpective primaries, according to the order of the ſigns.

The Moon

56. Moves round the earth in an orbit, whoſe ſemidiameter is about 60½ ſemidiameters of the earth; its eccentricity 3½ 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 degrees. 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 years 234 days. 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 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

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 sec. 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 days 5 hours.

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

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 then 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, 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.

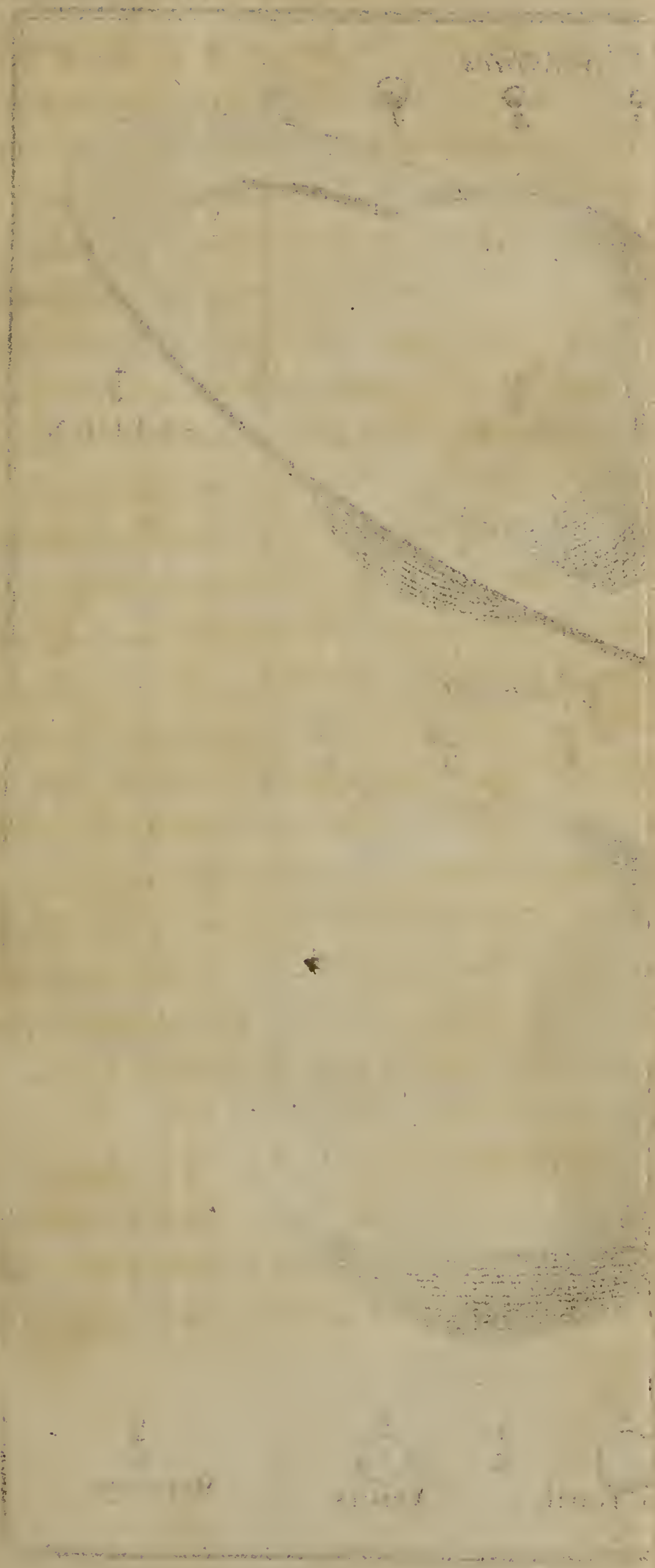
In fig. 14. a T b repreſents a part of the earth's orbit, S the ſun, T the earth, A C E G the moon's orbit. If the moon is at A, it will be on the ſame ſide of the earth with the ſun, or in conjunction; and the ſun will then be beyond the moon: therefore the ſun does not ſhine on that hemiſphere of the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

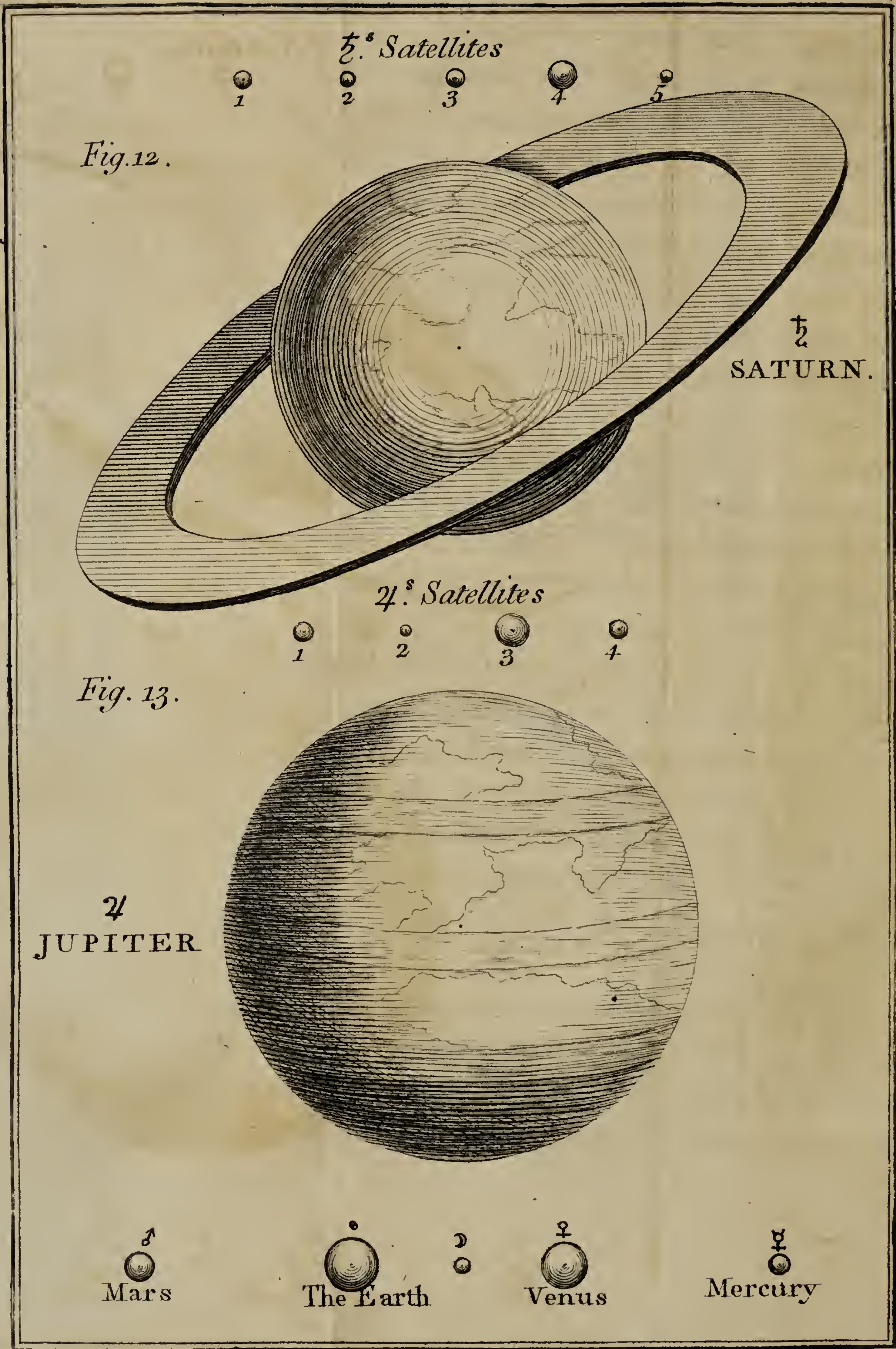
62. When

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, will 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 degrees: 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





Goodnight sculp

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, 14.384; 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 degrees; the ſecond deviates a little from the reſt.

66. A

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.

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

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.

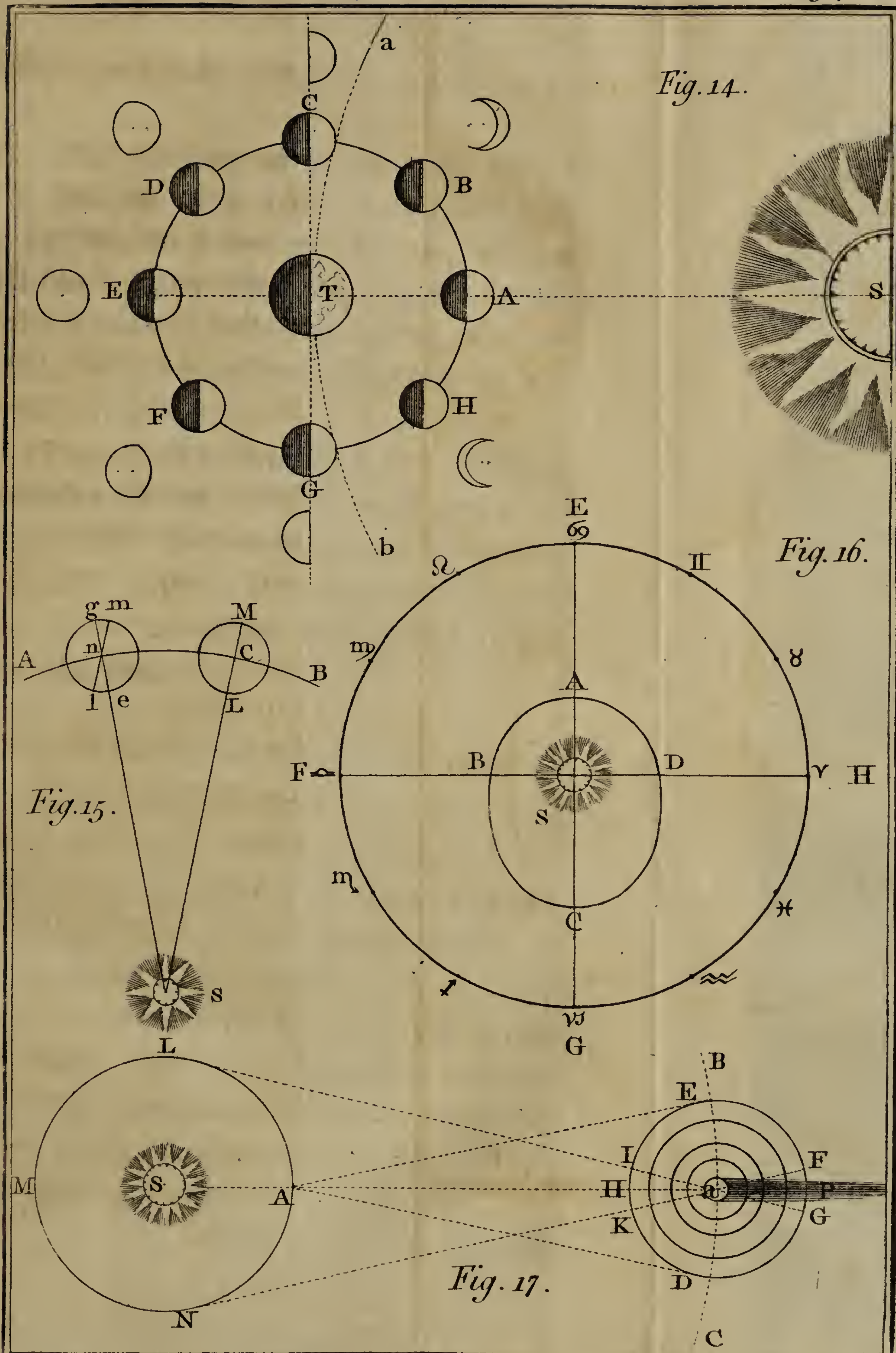
The apparent motion of any ſatellite is direct, as it paſſes from D, fig. 17. its greateſt elongation, through P, its ſuperior conjunction, to E, its greateſt elongation on the other ſide; its geocentric motion ſeen from the earth at A, being then from weſt to eaſt, *in conſequentia*, or according to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



Goodnight sculp

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.

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 center 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. IAK 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 will 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 thro' 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;

all; its apparent place in the 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, but the secondary P Y Q, passes thro' 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,

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

Fig. 18.

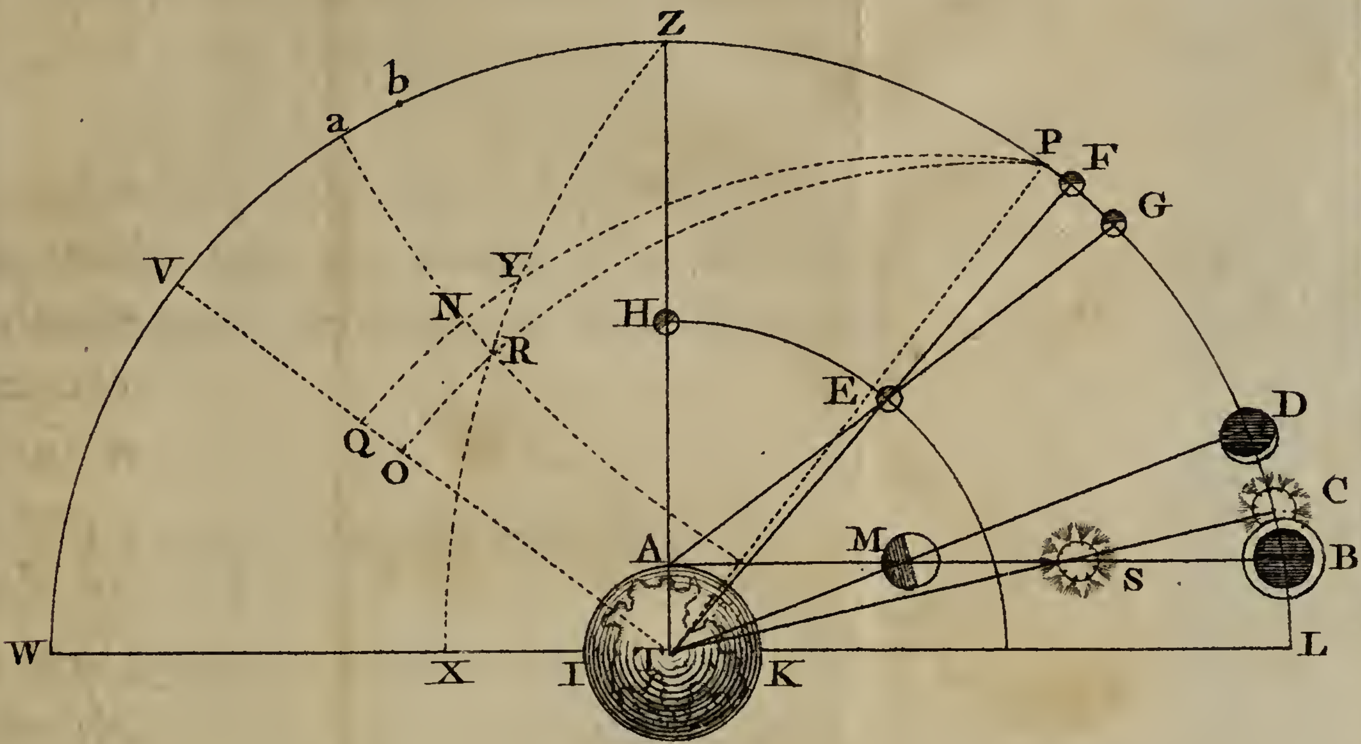
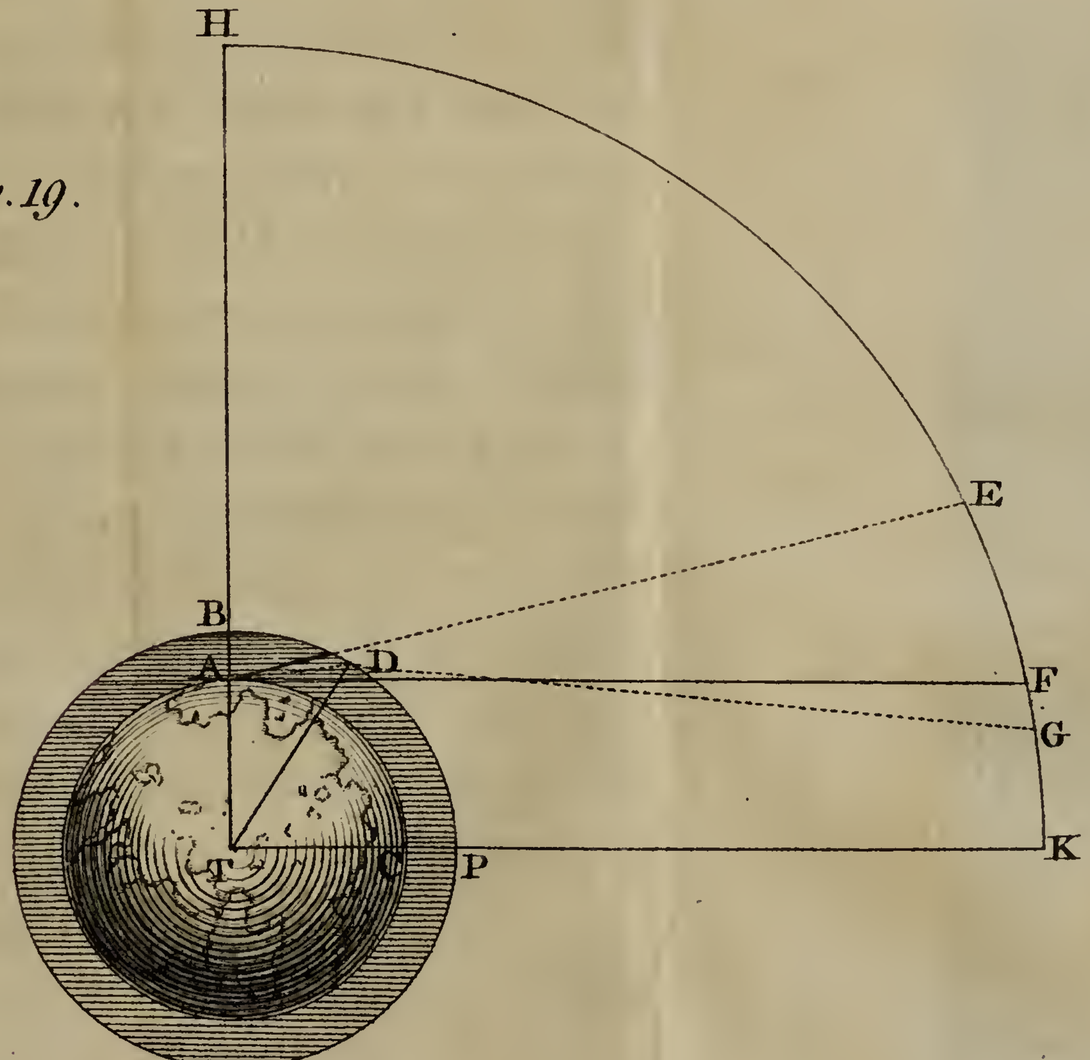


Fig. 19.



Goodnight sculp

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 m. 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

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 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

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 A B H.

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;

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 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.

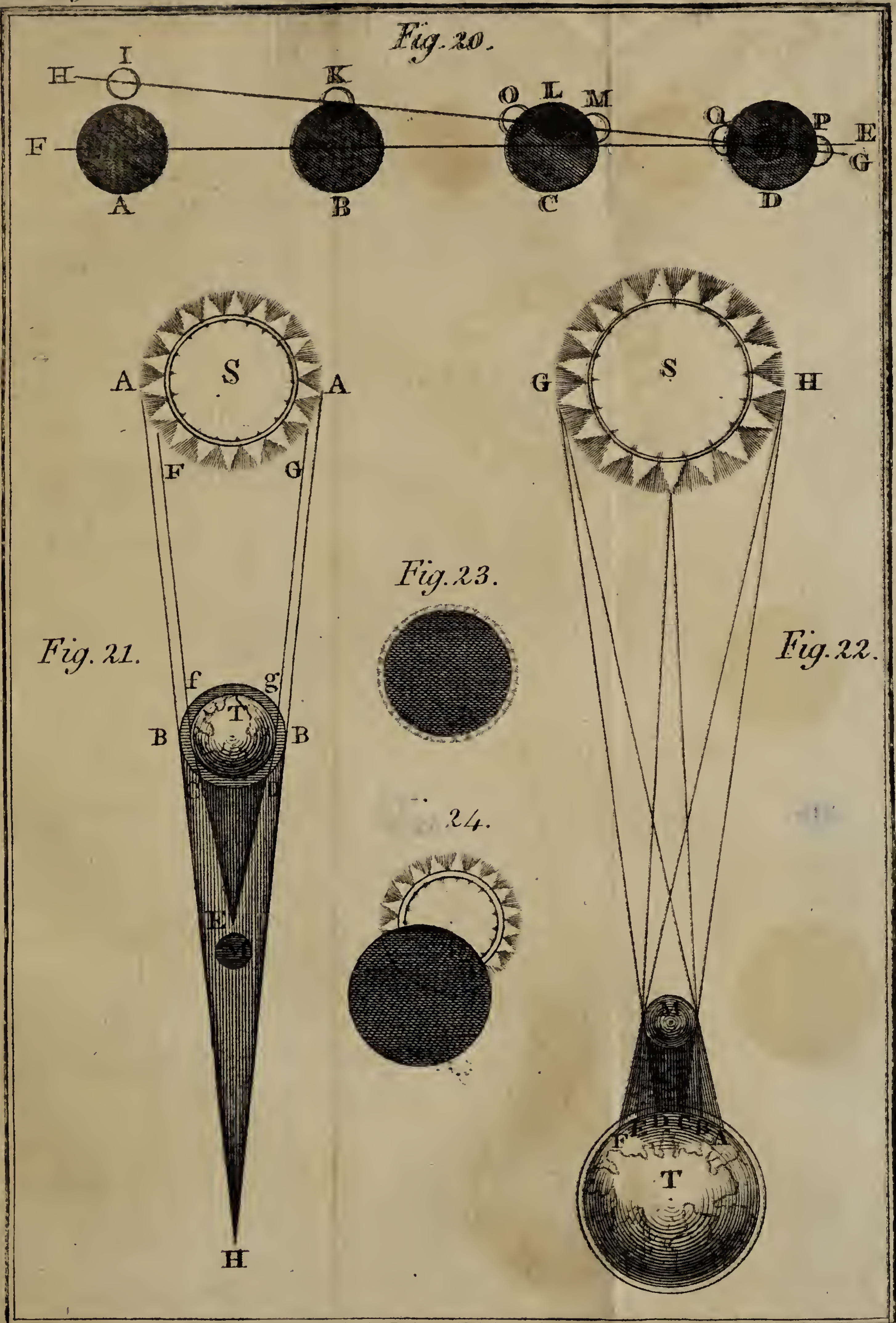
This diminiſhed light, which ſurrounds the ſhadow every way, is called the penumbra. An obſerver at B or E, can only ſee half the ſun's diameter, the reſt being hidden by the interpoſition of the moon. If the obſerver moves from B to C, or from E to D, the ſun will be more and more withdrawn from his 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

umbra only goes by, as it 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.

THE



Goodnight sculp

Fig. 25

The New

CELESTIAL GLOBE,

As Improved and Constructed by GEO: ADAMS

In 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

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,

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 ſemi-circle 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 ſemi-circle 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

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 divi-

ſion 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 on 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

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 biſſextile, 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

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 the first 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

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, NZÆSN.

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

tor 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 be- "cauſe 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

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,

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 ſemi-circular wire Æ F placed in the plane of the equator, carrying two indices, placed, one on each ſide of the meridian, 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 in this case bring the horary index as near as poſſible, and make an allowance of a few minutes.

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 NHS,

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

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 fixed 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;

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 ÆIQ

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. The 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

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 51 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 declination, 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 declination, 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 Sirius 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. 130. 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

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 alſo 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 the 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 is 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 terrestrial globe passes through London, and is called a first meridian; because from that point

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 Pacifick 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 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

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 Meditarranean, 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, in 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

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,

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 Finland, Peterſburgh in Ruſſia, to croſs a part of Moldavia and the Black Sea, thence it paſſes over a part of Turky, 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

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 moning at Cape Pasaro in Sicily.

PROBLEM

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

PROBLEM XI.

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

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 E L

154. Is that graduated circle which croſſes the equator in an angle of about $23\frac{1}{2}$ 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,

duated, 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 characters ♈ 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 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, the 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

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

ſent 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 $23\frac{1}{2}$ 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 *.

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

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

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 spheres, 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. Æ N Q S Æ 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

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.

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

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

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

the other, which is on the south side of it, the tropic of Capricorn.

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

The two polar circles are now 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 $23\frac{1}{2}$ 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 formerly 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 thro' 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 the other.

The

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 thro' 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

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 coloures 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

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 that 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 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

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 substracted from it gives the sun's true place in the ecliptic. Consequently it is the same thing, 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

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 h, ♑, 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

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 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

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 compleats 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

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 a 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

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 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

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 1 ½ tenth of an inch greater than that of the globe itſelf; if this plane be applied to 66 ½ 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:

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 degrees 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

circle will represent the horizon of that place. Thus for London, elevate the North-pole till 51°. 32′. on the strong brass meridian, cut the broad paper circle, and the globe is rectified.

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

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.

PROB.

* 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 this 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

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

* The Nautical Almanack is the best English Ephemeris extant.

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 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-

be tightned on any part of the globe, and puſhing it downwards will ſlacken it, that it may be removed to any other place, and then tightned 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

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. While 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 arti-

ficial

ficial 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,

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

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, or the difference of the latitude from 90 degrees.

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

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

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

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

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

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 becomes 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 eighteen 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 is out of the ſun's light, the greater part of it enjoys the benefit of twilight; there being only about $5\frac{1}{2}$ 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

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

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

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

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

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 12 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 14 h. 24 min. 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; (tho' 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 5 h. 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

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		☉ Setting		Length of Day.		Twilight.	
	h.	m.	h.	m.	h.	m.	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 Janario 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 fouthermoſt 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

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

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

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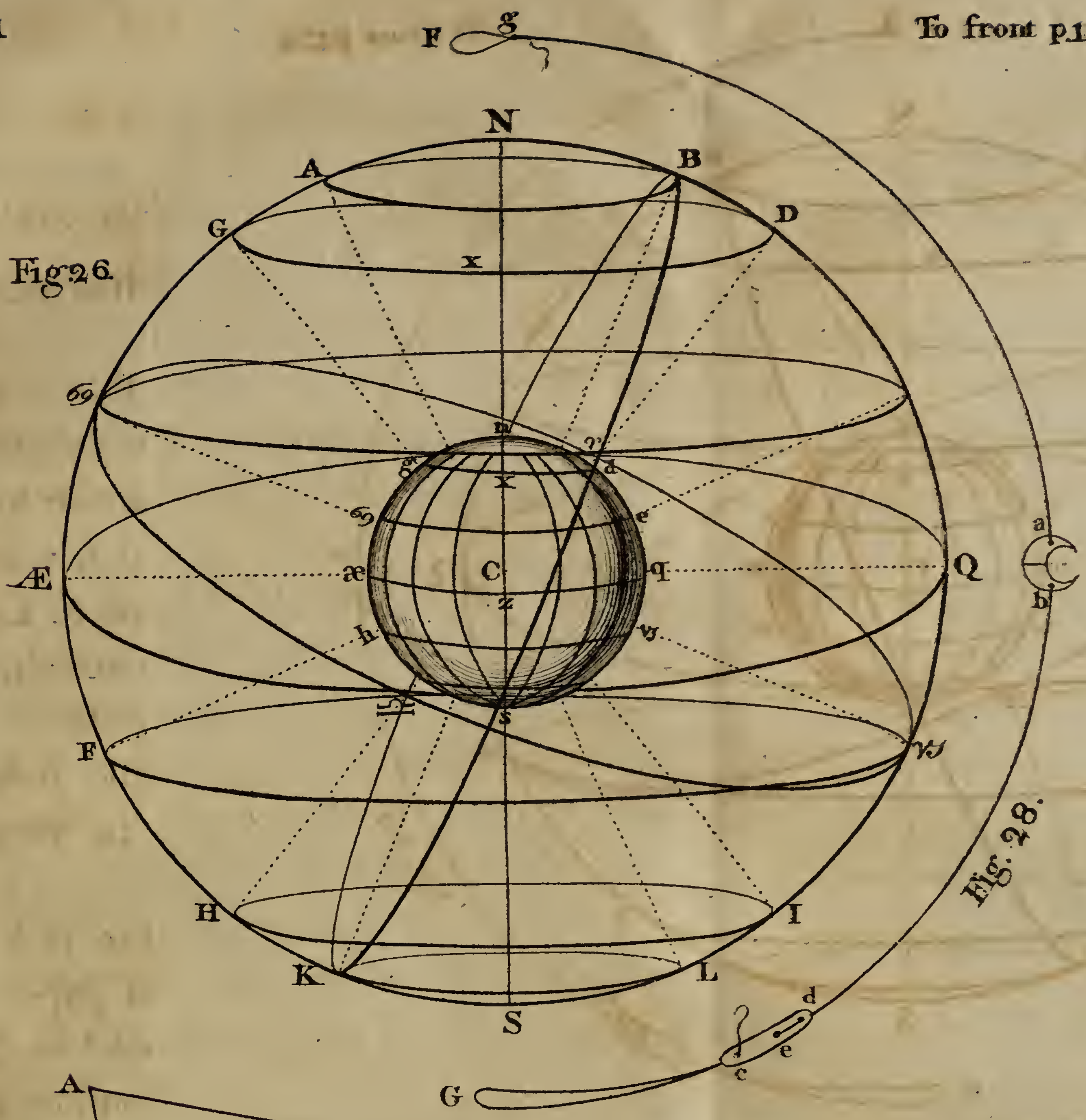


Fig. 26.

Fig. 28.

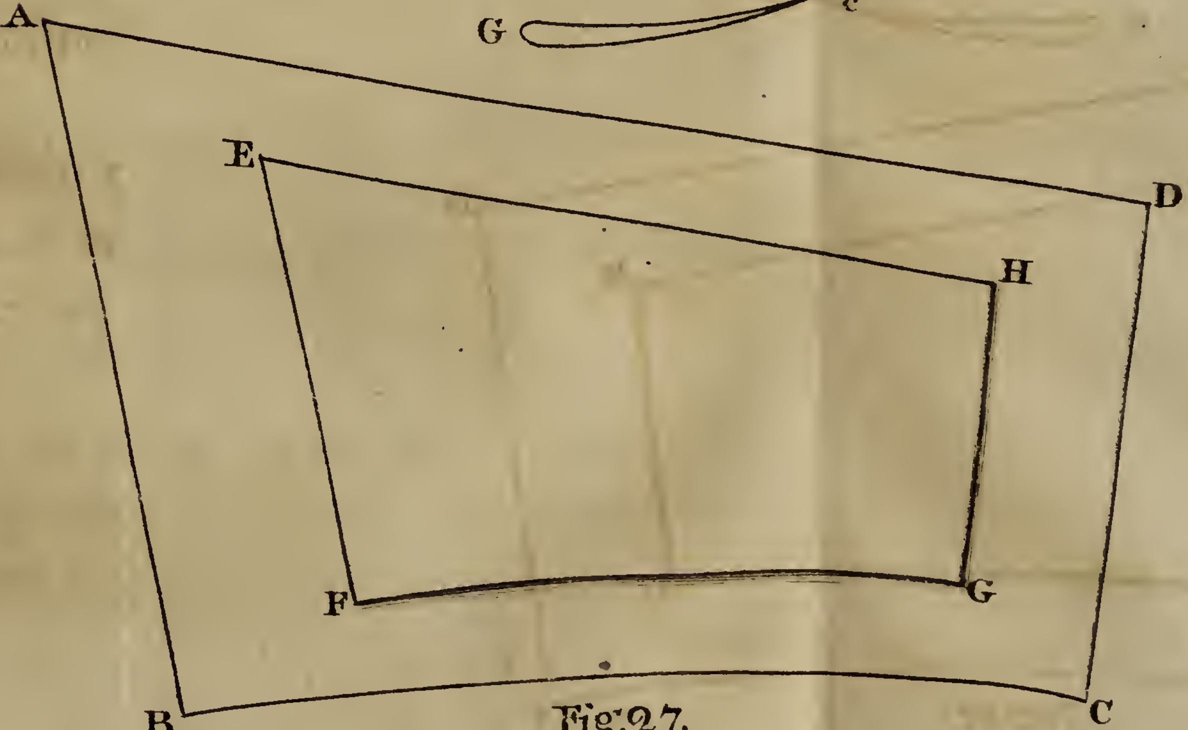


Fig. 27.

dually 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

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 38½ 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

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

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 ſubſtract 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 XLIV.

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

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

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

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

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

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,

tions, 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 back side 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,

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.

Thus for the 27th of July the sun's place is ♌ 4° 50′, find this on the ecliptic line upon the globe, where it will cut the 19th parallel from the equator.

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

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

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 dark-night, at the ſame inſtant; as well in 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 back ſide 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;

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 planets, 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

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, or that point which is directly under the obſerver's feet.

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

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 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 m. and that of the night 7 h. 20 m.

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

Wherefore the globe being rectified as above, and the artificial fun placed to the firft point of Cancer, and brought to the eaftern edge of the broad paper circle, and the horary index being fet to that XII which is moft elevated, on turning the globe from eaft to weft, until the artificial fun coincides with the weftern edge, the number of hours counted, which are paffed over by the horary index, is the length of the longeft day; their complement to twenty-four hours gives the length of the fhorteft night.

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

A climate is a fpace upon the furface of the earth, contained between two parallels of latitude, fo far diftant from each other, that the longeft day in one, differs half an hour from the longeft day in the other parallel.

The

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 encreaſe by a whole natural day, till they came 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 back ſide of the ſtrong braſs meridian, to

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 back ſide 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 ſide 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

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 attained, 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 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

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 $69\frac{1}{2}$ 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 nearly the distance sought; "provided the degrees of longitude be properly reduced to miles on the parallel on which they are measured: for a degree of longitude is not $69\frac{1}{2}$ English miles any where but at the equator; from which as the latitude decreases towards either pole, it becomes less and less till it vanishes into nothing at the poles themselves, viz. in 90 degrees of north or south latitude — Wherefore the quadrant of altitude will be also used here, as this will shew the distance in degrees of a great circle, of which 69 miles and ½ may be reckoned to a degree: and this is indeed the only method of obtaining the *true* distance, which ought to be measured on the arch of a *great* circle, and not on any parallel of latitude, which must be a lesser circle."

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

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

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 66 $\frac{1}{2}$ 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 $51\frac{1}{2}$ degrees north: when the sun is in the tropic of Cancer, the day is about $16\frac{1}{2}$ 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 $7\frac{1}{2}$ 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

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

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 20 and 21 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

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

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

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 thro' thoſe of Capricorn, through the Sculptor's frame, Eridanus, the ſtar Rigel 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

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 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 Saad, marked β in Pegaſus, under the head of Andromeda, and through the ſtar marked ϕ in the northern 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 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 thro' 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

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. 10 h. 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 10 h. 24 m. which is equal to 156 degrees. See the table at the end of the book for converting time into parts of the equinoctial.

Whence the fixed or firſt meridian ſought is thus obtained, and lies 10 h. 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 thro' the great Pacific ſea, and croſſes one of the Iſles of St. Bernard, and the Iſle des Mouches.

The next thing to be conſidered is the neareſt mean length of a tropical year, which

N is

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, 0 h. 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, 10 h. 24 m. upon the 298th day from the calends of January.

The tropical year thus reckoned exceeds the Egyptian year by 5 h. 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,

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

fore 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, aacording 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 10 h. 24 m. 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 *.

* The kalends of January begin from the noon of the preceding day; that is, from the noon of the day before the firſt day 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 10 h. 24 min. 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.

Add the epoch 298 to the days of the tropical reduction, and from their ſum ſub-

tract

tract 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.

dian. 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 d. 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

day of each month in any common almanack.

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

A circle of the 7 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

The literal character for the 1ſt of September is F; ſo alſo 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 15th 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

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. Re-

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, Oct. 25, A. J. P. 706.

	Retroceffion.			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 days 565		tropical time	1410565	23	58
epoch + 298		retroceffion +	29	12	2
863		Julian reduction	1410595	12	0
Julian days —595			the 3d year after biffextile.		
268					
for Auguft — 243					

		d.	h.	min.	
♎ Sept.	25				
	à kal. Jan.	268	23	58	fixed meridian.
	meridian dift. +		12	25	
The fun in the firft point of Libra Sept. 26,		269	12	23	at Alexandria.

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

269. To

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
substract 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

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 ſtile			
for new ſtile +	11	days			
	264	à kal. Jan. new ſtile			
for Auguſt —	243				

	d.	h.	min.
☉ in ♎ Sept. 21. in the fixed meridian à kal. Jan.	264	15	15
meridian diſtance +	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
ſubſtract diſt. ♈ à ♎	186	11	51
	78	13	48
for Feb.	59	0	0
The ſun in Aries at Greenwich, A. D. 1768, March	19	13	48

272. Having

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.	m.
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

Tropical days	735	to the tropical time	2110735	14	31
epoch +	298	retroceſſion +	44	3	29
	1033		2110779	18	0
Jul days + 1 —	780	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.	m.
☼ in Libra Sept. 21 in the fixed meridian à kal. Jan.	264	14	31
meridian diſtance +	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
diſtance from Aries to Libra	186	11	51
	78	13	4
for February	59		
The ſun in the firſt point of Aries at Greenwich, 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

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.

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 answer.
		—			
		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

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

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 Zeland; 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

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

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

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,

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

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 SSE and SbE; 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

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 cieling 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,

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 ½ 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

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

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

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 Sofala 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;

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

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 4 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 fifteen 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

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

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 underneath 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, entitled, "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

" 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
minutes	37	0	6
Right aſcenſion of ♈ ☉, upon the equinoctial day		2	59 paſt noon.

A. D.

A. D. 1770, the ſun will enter Aries, March 20, 1 h. 26 min.

		min.	ſec.
hours	1	0	9
minutes	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
minutes	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
minutes	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

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 19 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, against 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

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	36
	+	0	13
Right ascension ♈ ☉,	10	26	49

EXAMPLE

EXAMPLE III.

A. D. 1771, equinox March 20.

	h.	min.	sec.
Jan. 12,	4	22	46
	+	1	6
Right ascension ♈ ☉,	4	23	52
December 16,	6	22	58
	+	1	6
Right ascension ♈ ☉,	6	24	4

EXAMPLE IV.

A. D. 1772, equinox March 19.

Bissextile year.	h.	min.	sec.
February 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

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

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

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

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, ſubſtract 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

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 Ballance, 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

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 in 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 ſouthermoſt 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

brafs meridian, and fet the edge of a card thereto, holding it to the brafs meridian with your right hand, while you gradually turn the globe from weft to eaft with the other hand, and that point of the card which is upon the globe will then reprefent the interfection of that line upon the furface of the earth, which we have fuppofed to pafs from the center of the earth to the ftar; and as this point, though at reft, paffes over the parallel of London upon the globe, fo does the central ray, proceeding from the ftar, really pafs over every point of land, and fea, upon that part of the earth which is circumfcribed by the parallel of London.

Thus you will fee the ftar marked γ, in the head of Draco, pafs from London over the road to Briftol, and dart its perpendicular rays upon that city; then croffing the fea, it reaches Ireland between Kinfale and Cork, and leaving that kingdom, will fhine over the Atlantic Ocean, until it is perpendicular to the north cape of Newfoundland; whence it will be vertical to Efkimos, and pafs between lake Achona and the northern coaft of the gulph of St. Lawrence, then it will crofs St. James's Bay, Kriftino, &c.

and

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 Zeland, 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

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

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 commonly called Vega, but it should be Waki, in the Arabic Nesr Waki, signifies the stooping or falling Vultur, and marked α: this star is 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 Waki is 277 degrees, as London is west of Sardinia; 9 degrees subtracted from 977 degrees, leaves 268 degrees of right ascension,

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 Waki 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 ex-

tenſive

tensive 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

West of London.

Rigt. Asc.		Decl. and Lat.			W. Lon.
267½	Knee of Hercules	θ	37	Carthagena, Old Spain	0½
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, South America	70
175	Deneb Alafad, Lyon'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.

Rigt. 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	27½	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 south wing	ε	33½	Frontiers of Turkey in Asia, and Desert Arabia	41

The

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 was 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

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.

Westward.

Rigt. Asc.		Decl. and Lat.			W. Lon.
14	Girdle of Andromeda, Mizar	β	34	Kichuans, Louisiana	96
18	Cassiopea's thigh	δ	59	P. Walesfort, 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.

Rigt. 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 Lyon's mouth	ε	25	Nahassa, in Egypt	33
149	Regulus, Lyon'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

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.

Rigt. Asc.			Decl. and Lat.		W. Lon.
90	First star in the foot of Castor	μ	22½	Isles of Tres Marias, New Spain	108
113	Head of Pollux	β	29	Sea near C. Escondid, Florida	85
139	Hydra's heart	α	7½	Yamari, a branch of the Amazonan River	61
149	Regulus, Lyon's heart	α	13	Sea 12° E. of the Antilles	49
175	Lyon'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.

Eaſtward.

Rigt. Aſc.		Decl. and Lat.			Eaſt 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	ν	39	S. Eaſt 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	93
29	Atair, in the Eagle	α	8	Eaſtern Sea, or Coaſt of Malacca	95

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 the zenith.

Weſtward.

Rigt. Aſc.		Decl. and Lat.			Weſt 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.

Rigt. Aſc.		Decl. and Lat.			Eaſt Lon.
321	Side of Cepheus	β	70	Fro. Sea near Iſle Wardus, Laponia	32
328	Shoulder 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

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.

Rigt. Aſc.		Decl. and Lat.			Weſt Lon.
290	The Swan's beak	β	28	Gulph Mexico, 3° S. Miſiſippi	88
294	Firſt in the Swan's wing	δ	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.

Rigt. Asc.		Decl. and Lat.			East 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 phœnomena 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

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

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 time 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

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, three 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 objects 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 66½ degrees, which is the latitude of the northern

polar

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 and place her 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 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 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.

30. 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

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 than 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

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*

* See the Rev. Mr. Coſtard's Hiſtory of Aſtronomy, p. 19.

I. *Al Sheratân*, 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 ε and ρ.

III. *Al Thuraiya*, the Pleiades.

IV. *Al Debarân*, the Bull's eye.

V. *Al Heb'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 φάτνη, i. e. Præsepe.

IX. *Al Terphah*, the Lyon's eye marked μ.

X. *Al Geb'ha*, the ſtar in the Lyon's mane marked ζ.

XI. *Al Zub'rah*, the ſtars in the Lyon's rump marked δ and θ.

XII. *Al Serphah*, the Lyon'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 ι $\varkappa$.

XVI. *Al Zubâna*, 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-Iclîl*, theſe are the four ſtars in Scorpio marked ν β δ π.

XVIII. *Al*

XVIII. *Al Kalb,* the ſcorpion's heart marked α, more fully *Kalbalakrab*; 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 *Lâſah,* the true name is *Shaulah.*

XX. *Al Nâaim,* theſe are eight ſtars in Sagittary, marked $\gamma\ \delta\ \varepsilon\ \lambda\ \mu\ \sigma\ \varphi\ \psi$; 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 Dâbih,* three ſtars in Capricorn, marked $\alpha\ \beta\ \nu$.

XXIII. *Sad Al Bula,* the ſtars marked ν in the hand of Aquarius.

XXIV. *Sad Al Suûd,* the ſtars marked β and ζ in Aquarius.

XXV. *Sad Al Achbiyah*, three ſtars in Aquarius marked γ ξ θ.

XXVI. *Al Pherg al Mukaddem*, the ſtars marked α and β in Pegaſus.

XXVII. *Al Pherg al Muacchir*, 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

duated 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.

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 sha-

dows

dows of his two ſtrings always united in one diſtinct ſhadow, that his obſervation may be compleat, 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 a-croſs 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 day of January, A. D. 1751, old ſtile; 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 afcenfion of the pole ftar when it is lefs than the fun's, the remainder will be the time of the ftar's coming to the meridian.

Then, as before, hang up two plumb lines, between your eye and the polar ftar.

PROBLEM LVI.

Of the equation of time.

306. As time flows with great regularity, it is impoffible to meafure it accurately, and compare its feveral intervals with each other, but by the motion of fome of the heavenly bodies, whofe progrefs is as uniform and regular as itfelf.

Ancient aftronomers looked upon the fun to be fufficiently regular for this purpofe; but by the accurate obfervations of later aftronomers, it is found that neither the days, nor even the hours, as meafured by the fun's apparent motion, are of an equal length on two accounts.

1ft, A natural or folar day of 24 hours, is that fpace of time the fun takes up in paffing from any particular meridian to the fame again; and one revolution of the earth, with

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

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

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

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

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 conſtitute 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 $66\frac{1}{2}$ degrees, bring that meridian or hour circle,

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)

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

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

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

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 plomb-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

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 plomb-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 6 h. 30 min. and also at 10 h. 30 min. in the morning. At 8 h. 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,

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

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

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 plomb 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

The plomb 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 plomb 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 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

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

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

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

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

Fig. 30.

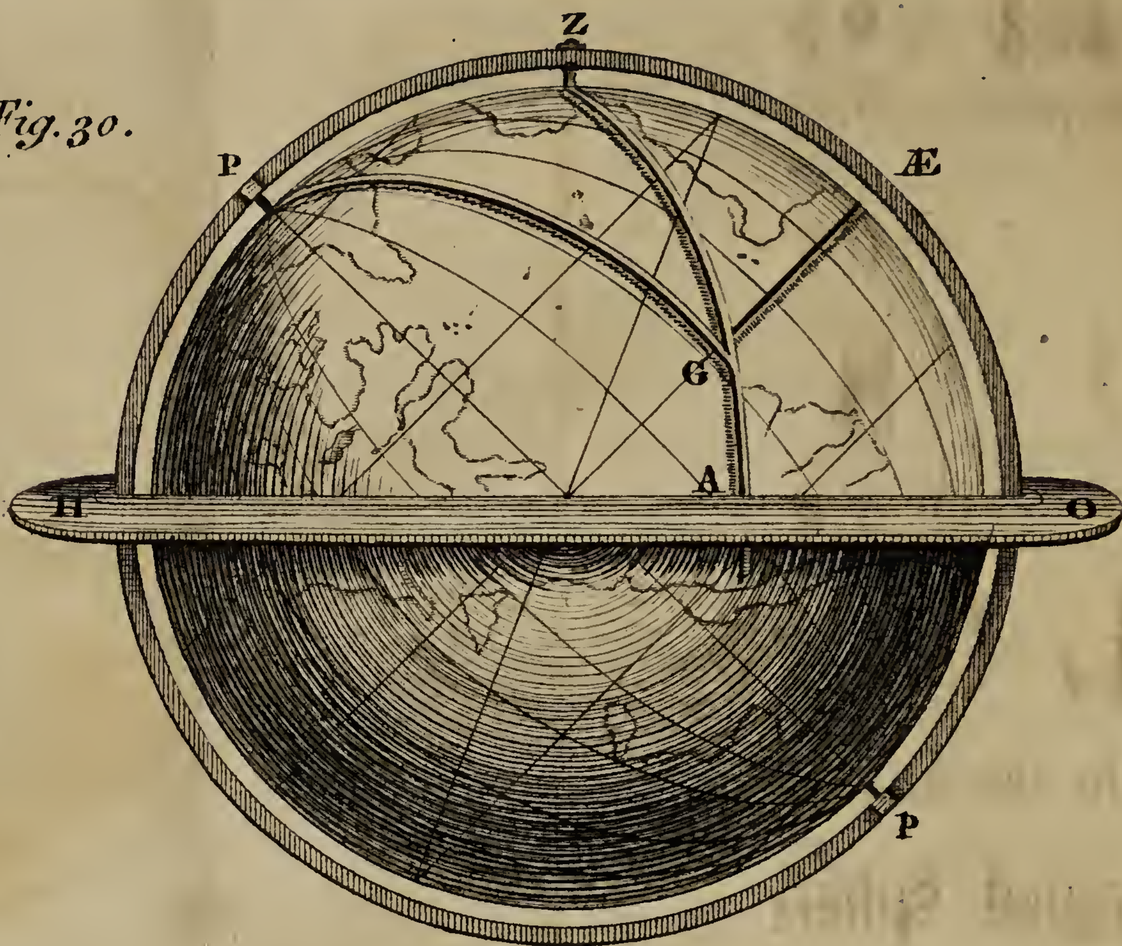


Fig. 29.

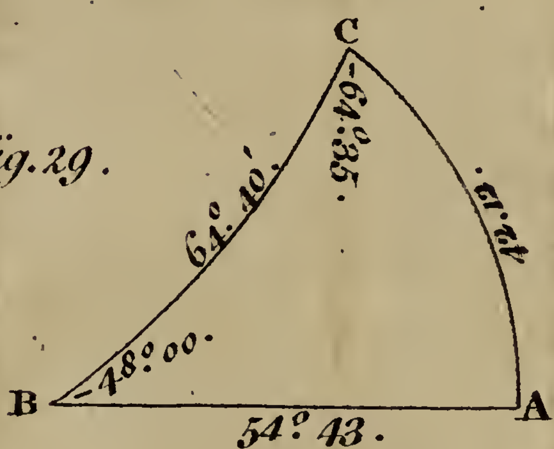


Fig. 31.

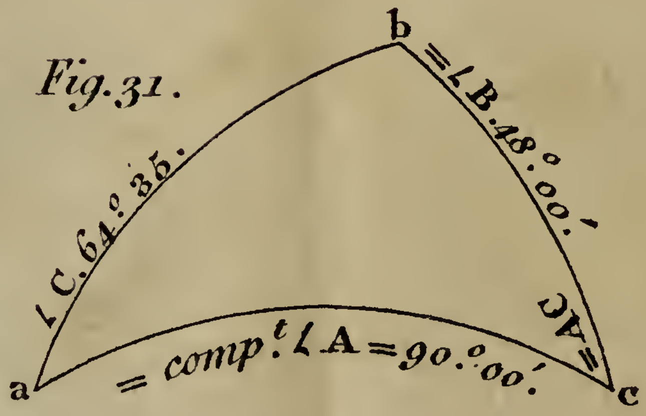
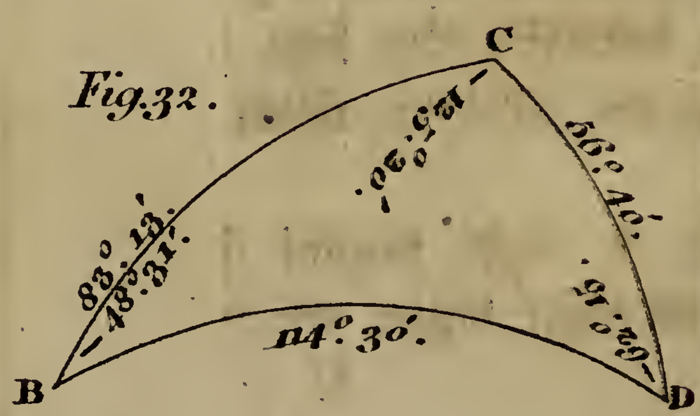


Fig. 32.



Goodnight sculp

THE USE OF THE GLOBES

In the SOLUTION of Right Angled Spherical Triangles.

326. A Spherical triangle is formed upon the ſurface of a globe by the interſection of 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 ABC, 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 AC, and number the same quantity on the strong brass

brafs meridian from Æ, the equator to Z, the zenith; there fix the quadrant of altitude. Bring that meridian which paffes through London under the brafs meridian, and count 64° 40′, the meafure of the hypothenufe, on the quadrant downwards from Z to G, and move it till the point G interfects the equator, and the triangle Z G Æ will be formed.

The fide Æ Z reprefents the given fide A C, the hypothenufe B C is reprefented by the arch Z G, the required fide A B is reprefented by G Æ an arch of the equator, its meafure 54° 43′, between Æ and G is the quantity fought; the angle A C B, is reprefented by the angle G Z Æ, and its meafure 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 meafure of the fide B A, 54° 43′, elevate the pole P agreeable thereto, and reckon the fame from Æ to Z; there fix the quadrant of altitude; number the other leg A C, 42° 12′ from Æ to G on the equator (the meridian paffing 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	BC	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		the angle	ACB
					the 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 angle triangle A B C, fig. 29. are given

$$\text{The legs}\left\{\begin{array}{lcc} & \circ & \prime \\ AB & 54 & 43 \\ AC & 42 & 12 \end{array}\right\}\text{to find}\left\{\begin{array}{l} \text{the hyp.} \quad CB \\ \text{the angles}\left\{\begin{array}{l} ACB \\ ABC \end{array}\right. \end{array}\right.$$

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°

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

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 B C D, 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 B C 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 C D, and reckon its opposite angle D B C, 48° 31′, on the equator from the point ♎ at

at G eaſtward, towards Æ, where ſtop the globe, and bring the mark upon the quadrant to coincide at G with the meridian P G, which paſſes thro' ♎, then the arch P G will contain 114° 30′, the meaſure of the required ſide B D; and the arch H A in the horizon 125° 20′, will be the meaſure of the angle B C D; the other angle P G G, equal to the required angle B D C, 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

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

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

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 B C D, 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 C D, 56° 40′, from P to Z, and bring Z into the zenith,

zenith, and fix the quadrant there alſo; count the angle B D C, 62° 51′ on the equator, from ♎ to Æ; number the angle B C D, 125° 30′, upon the horizon from H to A, and bring the quadrant to A; then P G, 114° 30′, will be equal to B D the required ſide, G Z 83° 13′ equal to the other required ſide B C, and the angle P G Z equal to the angle D B C, may be found by art. 332, 339.

CASE V.

PROBLEM LXXV.

Three ſides given, to find the angle.

In the oblique angled triangle B C D, 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°

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,

blem, 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

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 $66\frac{1}{2}$ 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 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

The angle ♋ ☼ P, which is the angle that the meridian passing by the sun make 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 thro' ♎, 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 Mr. 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

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 Bd Gi, 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 thro'

♎ 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 to 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

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 m. 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

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.

337. 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

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 thro' ♎, 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 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 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

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 m. from noon, which is 51 min. paſt 6 in the morning; or at 9 min. paſt 5 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 deg. 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

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 gtobe, 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

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 diſk, 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

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 m. 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 deg. 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,

drant, 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 90th degree from the points wherein it interſects the horizon, and conſequently thoſe points themſelves; the diſtance of the nonageſimal and mid-heaven

Y points

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

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 thro' 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,

gesimal, 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′,

Fig. 33.

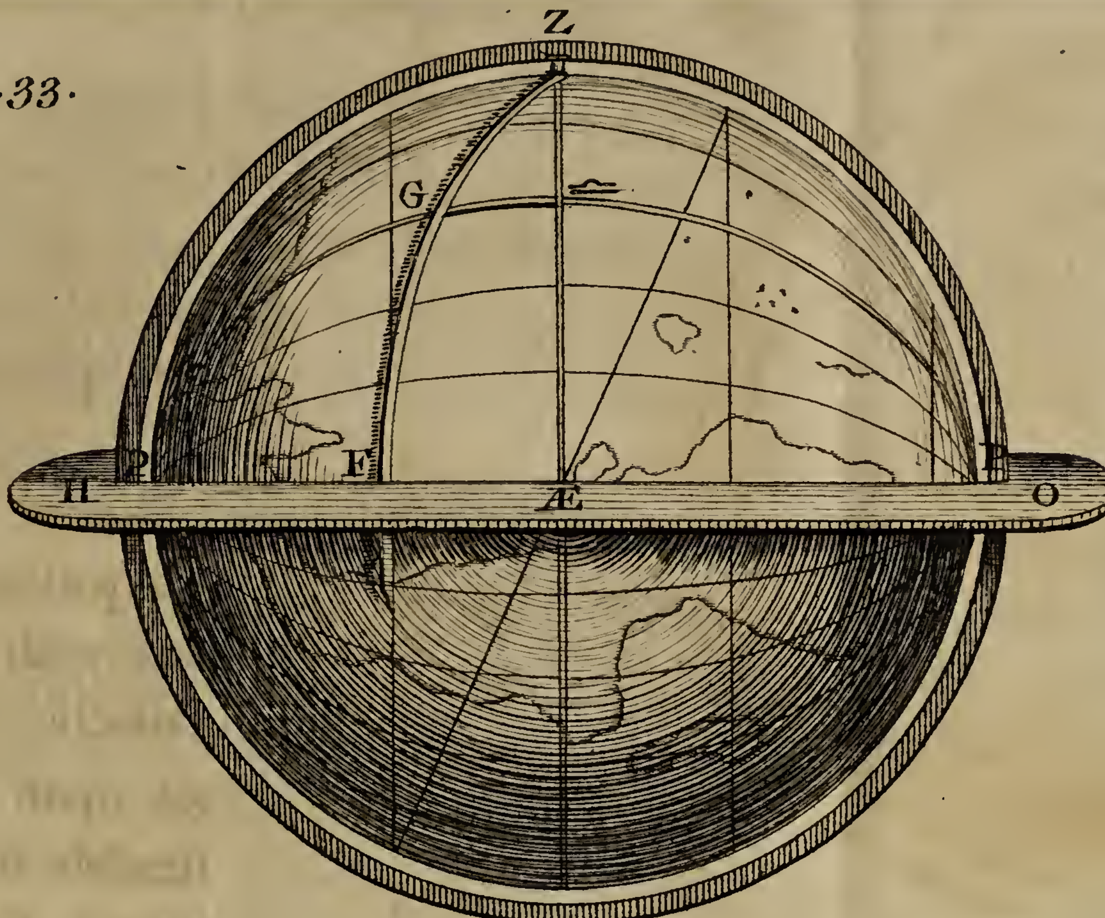
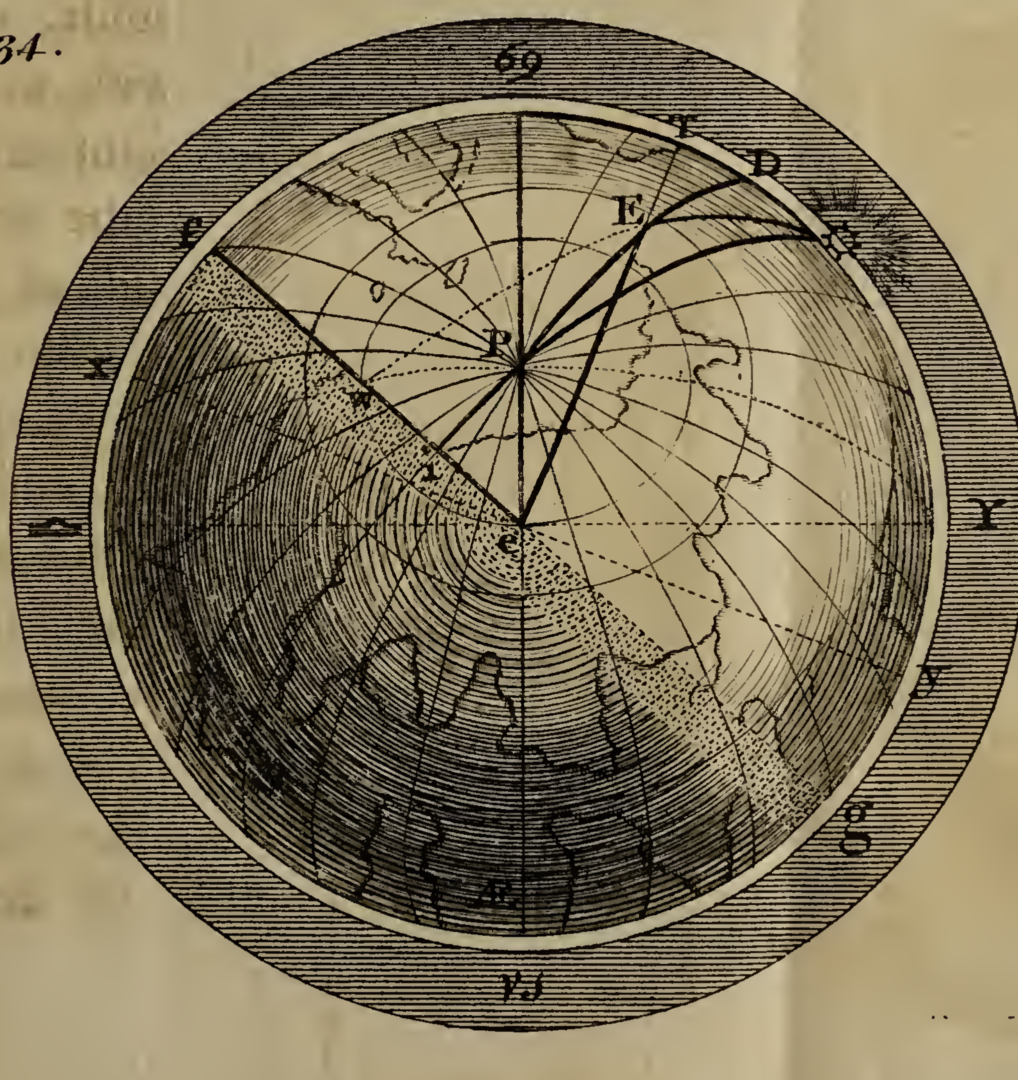


Fig. 34.



Goodnight sculp

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,

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,

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 f ✳ 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

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, politicks, &c. we have judged it neceſſary to add the following problems, as a farther elucidation of the two former, art. 302 and 303.

PROBLEM

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

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

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

Fig. 35.

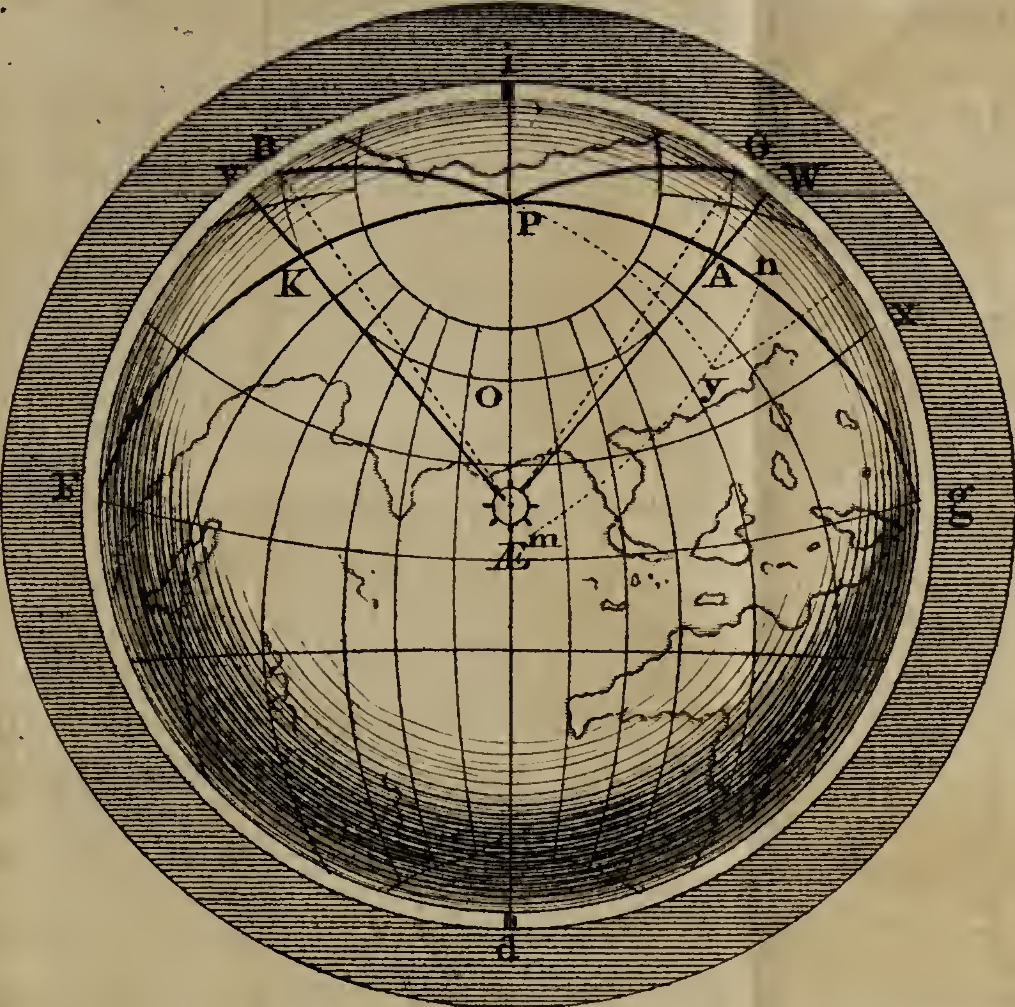


Fig. 36.

Goodnight sculp

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

EXAMPLE II.

Given, 26° 30′, the quantity of the preceſſion to find the time.

$$
\begin{array}{r l}
 & 26^{\circ}\ 30' \\
\text{Multiply by} & 60 \\
\hline
 & 1590 \text{ minutes.} \\
\text{Multiply by} & 60 \\
\hline
\text{Divide by } 50) & 95400 \text{ ſeconds.} \\
\hline
\text{Anſwer} - & 1908 \text{ years.}
\end{array}
$$

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

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 66½ 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

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.

Lineal Characters.	Days in each Month.		Days à Kal. Jan.
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	42	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. H.	M.	S.	February. H.	M.	S.	March. H.	M.	S.	Days
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	6		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
7	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	85		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

F I N I S.

A CATALOGUE OF Mathematical, Philoſophical, and Optical INSTRUMENTS,

Made under the Inspection and Direction of

GEORGE ADAMS,

Mathematical Inſtrument-Maker to His Majesty GEORGE III.

At the Sign of Tycho Brahe's Head, N°. 60, in Fleet-Street, London:

Where Gentlemen and Ladies, Merchants, &c. may be ſupplied with Inſtruments which are invented and improved by him, as well as with thoſe contrived by the ableſt Mathematicians in Europe.

THE Study of the Mathematicks being now become a neceſſary Part of every Gentleman's Education, we need not wonder at the great Progreſs which this Science has, of late Years, made in moſt Parts of Europe; ſince it contains ſuch an inexhauſtible Fund of uſeful Knowledge, as is ſufficient to gratify every Taſte, and employ every Talent. The nobleſt Genius may, in the Purſuit of it, exert his utmoſt Faculties; and the meaneſt will not fail of finding ſomething that is within his Reach. The Theory affords an ample Field to the ſpeculative Part of Mankind, and the Practice is productive of ſeveral Advantages to Men of Action and Buſineſs.

Mathematical Inſtruments are the Means by which the Sciences of Geometry, Philoſophy, Aſtronomy, and Opticks, are rendered uſeful in all the common and neceſſary Occurrences of human Life. By their Aſſiſtance an abſtracted and unprofitable Speculation, is made beneficial in a thouſand Inſtances: in a Word, they not only enable us to connect Theory with Practice, but alſo inſtruct us how to turn bare Contemplation into the moſt ſubſtantial Uſe, by making one of the moſt ſerviceable Branches of Learning, the natural Way of rendering this Knowledge general and diffuſive.

The Knowledge of theſe leads to that of practical Mathematicks, and experimental Philo-

Philosophy; so that the Uses of mathematical Instruments, make perhaps one of the most serviceable Branches of Learning in the whole World; and the natural Way, therefore, of rendering this Knowledge general and diffusive, is by making that of its Instruments so.

As practical Mathematicks, and experimental Philosophy, teach us the Powers of Nature, the Properties of natural Bodies, and their mutual Actions on one another; this Knowledge cannot be attained without Instruments, and the Conclusions and Proofs we expect from it, depend very much upon their Exactness. In order therefore to give a sufficient Satisfaction to those who honour me with their Custom, it is my particular and greatest Aim to produce such Instruments as may facilitate the Progress of mathematical and philosophical Learning.

In all my Performances I endeavour not to augment the Instruments with superfluous Ornaments, that they may be of frequent Use to those of middling Fortunes, and also that their Neatness may render them not unworthy of a Place in the Cabinet of the Curious.

That

That their Exactneſs may be particularly attended to, I always inſpect and direct the ſeveral Pieces myſelf, ſee them all combined in my own Houſe, and finiſh the moſt curious Parts thereof with my own Hands. That the Conſtruction may be as ſimple and ſubſtantial as the Uſe of each Inſtrument will admit, it is my conſtant Study to contrive them in ſuch a Manner that they may be managed with the greateſt Eaſe. I alſo have Reſpect to their being made applicable to ſeveral Operations, eſpecially when the Extent of their Uſes does not prejudice their Simplicity, to the End that Inſtruments may not be multiplied without Neceſſity.

In the following Catalogue I have ranged the Inſtruments in Claſſes under the Heads of their ſeveral Branches, and have numbered each particular Inſtrument, ſo that if a Gentleman is deſirous of any one or more of them, and is at a Diſtance from London, he need only ſend me the Numbers adjoining to thoſe he intends to purchaſe, and he ſhall be ſerved with Fidelity, and at the loweſt Prices.

INSTRUMENTS for Geometry, Drawing, &c.

VAriety of pocket-caſes of drawing inſtruments, in ſilver, braſs, ivory, or wood, from 10s. 6d. to 5l. 5s. Theſe contain more or leſs of the following articles, which limit their price.

1 Plain compaſſes for meaſuring lines, &c.

2 Drawing compaſſes with moveable points, viz. an ink point for ſweeping circles, or arches of any determinate thickneſs, and a black lead point.

3 Drawing pens, either with or without a protracting pin.

4 Sectors for finding proportions between quantities of the ſame kind, as between lines and lines, ſurfaces and ſurfaces, &c. either of box, ivory, braſs, ſilver, &c.

5 Plain ſcales, or
6 Square protractors, or } either of box, ivory, braſs, ſilver, &c.
7 Parallel rules, are

8 Semicircle protractors, of braſs.

In the beſt caſes, the compaſſes are always made with ſteel joints, and the knibs of all the pens are made to open with a joint, in order to clean them, in which are alſo ſometimes put,

9 Hair-compaſſes, ſo contrived on the inſide of one of the legs, that an extent may be taken to an hair's breadth.

10 Circular (or bow) compaſſes, with which a circle as ſmall as a pin's head may be deſcribed.

In

In a magazine-caſe of drawing inſtruments, is generally contained all the above inſtruments, together with the following particulars,

11 Drawing compaſſes, with moveable legs longer than thoſe of No. 2.

12 Strong compaſſes, with calliper and cutting points.

13 Beam compaſſes for drawing larger circles, and taking larger extents.

14 Proportionable compaſſes for the ready diminiſhing plans or drawings, in any aſſigned proportion.

15 Twelve-inch braſs ſectors of a new conſtruction.

16 Triangular compaſſes for tranferring three points at once, from a map or any drawing to another copy.

17 A pointrel and feeder, having at its upper end an oval plate for clearing the drawing pen of any dirt or grit that may happen between the knibs, and in the middle thereof is a protracting pin.

18 Elliptical compaſſes for deſcribing ellipſis of various excentricities.

19 Bows for drawing curved lines.

20 Port craiyons.

21 Large plain ſcales.
22 Plotting ſcales.
23 Protractors.
} Sometimes theſe are all made in one inſtrument.

24 Plain and parallel rules of ſeveral ſizes.

25 Ivory pallates for Indian ink and colours.

26 Gunners callippers.

27 The regular ſolids, or platonick bodies cut in wood.

28 Cy-

28 Cylinder bisected.
29 Cones with all their proper sections.
30 Flat plates, for describing the conic sections upon paper, designed for those who are studying that branch of science.

In these magazine cases, gentlemen may have what number of instruments they think proper.

Rules of all sorts, for measuring of timber, stone, painting, brick-work, *&c.* at the usual prices.

Surveying Instruments, *&c.*

31 PLAIN tables, with an index and sights, whereby the draught or plan is taken on the spot, without any future protraction, having a compass fitted to one of its sides, and the whole fixed upon a ball socket, with a three legg'd staff, upon which it may be turn'd round, or fasten'd with a screw, as occasion requires.

32 Beighton's plain tables, with an index, whereby the line of sights is always over the center of the table, the station lines drawn parallel to those measured on the land; and the table set horizontal by a spirit level. In this table the papers being square, are readily laid together and compose the whole survey in one view.

Theodolites for measuring angles, distances, altitudes, &c. Those instruments are made various ways, some being more

 simple

44 Pantographers, for reducing, or enlarging, or copying plans of surveys, pictures of any kind, and reducing shadows of the human side face, and this without any previous habit of drawing.

45 Pedometers to measure the way in walking.

46 Perambulators, way-wisers, or measuring-wheels, ditto for coaches.

47 Major General Williamson's new instrument for elevating pieces of ordnance.

*47 Dr. Pollock's new universal instrument of gunnery.

Optical Instruments.

		l.	s.	d.
48	REflecting telescopes, 12 inch.	5	5	0
49	Dittto 18 inches ——	8	8	0
50	Ditto 2 feet ——	12	12	0
51	Ditto on a rack stand ——	21	0	0
52	Achromatic prospects for the pocket —— ——	1	16	0
53	Achromatic telescopes, either in nurse skin for the pocket, or mahogany tubes, 2 feet ——	2	2	6
54	Ditto 3 feet ——	3	3	0
55	Ditto 4 feet —— ——	4	4	0

And so in proportion for any other length. All other sorts of refracting telescopes at the usual prices.

56	Wilson's pocket microscope	2	2	0
57	Ditto —— ——	2	12	6
58	Ellis's aquatic microscope —	2	2	0

59 Ellis's

		£	s	d
59	Ellis's and Wilson's microscope in one case —— ——	4	15	6
60	A single and double aquatic microscope —— ——	7	7	0
61	The double constructed microscope —— ——	6	6	0
62	Ditto with a triangular foot in a flat mahogany case ——	8	8	0
63	Culpepper's double microscope	3	3	0
64	A solar microscope ——	4	14	6
65	A ditto —— ——	5	15	6
66	The new variable microscope	21	0	0
67	A solar microscope, to be applied to a new invented camera obscura, that may be used either in the sun-shine, or with a lamp contrived for that purpose in winter evenings ——	29	0	0
68	A pocket camera obscura	0	10	6
69	A ditto —— ——	1	1	0
70	A ditto, larger ——	1	5	0
71	A pyramidical camera obscura in wainscot ——	3	3	0
72	Ditto in mahogany ——	4	14	6
*72	Ditto for copying of pictures, drawing still life, portraits, &c. ——	8	8	0
73	An instrument for taking perspective views ——	6	6	0
74	Concave and convex mirrors, from —— 7s. 6d. to	26	0	0
75	Prisms, from —— 7s. 6d. to	2	2	0
76	Zograscopes for viewing prints, from —— 16s. to	3	3	0
77	Opera glasses ——	0	8	0

78 Ditto

		£	s.	d.
78	Ditto —— ——	0	15	0
79	Ditto —— ——	1	1	0
80	Ditto —— ——	1	11	6
81	Reading glaſſes in variety of frames, from —— 2s. 6d. to	3	13	6
82	Spectacles for the noſe ——	0	1	0
83	Ditto —— ——	0	3	6
84	Temple ſpectacles ——	0	3	0
85	Ditto ——	0	5	0
86	Ditto —— ——	0	8	0
87	Ditto ſilver —— ——	0	15	0
88	Silver double joint ſpectacles, which neither preſs the noſe nor temples —— ——	1	1	0
89	Ditto in ſteel ——	0	14	0
90	Ditto —— ——	0	9	0
91	Treble joint ſpectacles for the ladies.			
92	Ditto in ſilver.			
93	Spectacles of brazil pebbles either in ſteel or ſilver, at the uſual prices.			
94	Concave glaſſes for myopes or ſhort ſighted perſons, in great variety.			
95	Magick Lanthorns.			

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		£	s.	d.
96	AIR pumps excluſive of any apparatus.			
97	Single barrelled ——	2	2	0
98	Small double barrelled ——	4	4	0
99	Ditto larger ——	6	6	0

100 A

100	A large table air pump —	10	10	0
101	A large ſtanding air pump	21	0	0
	The apparatus to either of theſe according to the deſire of the purchaſer.			
102	Portable barometers ——	2	2	0
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104	Ditto with mercurial thermometers —— ——	4	4	0
105	Ditto with ditto and hygrometers —— ——	4	14	0
106	Ditto with ditto and ditto, with glaſs doors ——	6	6	0
107	Other barometers with open ciſterns of ſeveral curious conſtructions, of a new contrivance, with diagonal barometers, either with ſingle, double, or triple tubes. Wheel barometers, &c. all at reaſonable prices.			
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Aſtronomical and Geographical Inſtruments.

111 NEW Globes accurately delineated, neatly engraved, and adapted to an apparatus eaſy in application, and exten-

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	five in their use, 18 inches diameter, in stained frames —	9	9	0
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113	Ditto in carved frames —	24	0	0
114	New globes, 12 inches diameter in stained frames ———	5	5	0
115	Ditto in mahogany frames	6	16	6
116	New globes, 6 inches diameter in stained frames.			
117	Ditto in mahogany frames.			
118	Globes 3 inches diameter in frames —— ——	1	11	6
119	Ditto in black cases for the pocket —— ——	0	10	6
120	Globes mounted with wheel-work, at various prices.			
121	Armillary spheres, 12 inches diameter ———	21	0	0
122	An armillary dialling sphere, so contrived as to explain the reason and nature, as well as to solve the most useful problems in spherics, and illustrate the theory of dialling, and is itself an universal sun-dial.			
123	A sphere shewing the real and apparent motion of the heavens, and solving the problems depending thereon.			
124	A planetarium, by which the annual motion of the planets, their situations and positions with respect to the earth and sun, as well as to each other,			

with

with their direct stationary and retrograde appearances, are clearly illustrated —— 18 18 0

125 A tellurian, which explains the diurnal and annual motions of the earth and moon; shews the inclination and retrograde motion of the moon's orbit, and thereby the causes of the eclipses of the sun and moon, the causes of day and night, the vicissitudes of the seasons, the phases of the moon, the difference between a periodical and synodical month, the rising, southing, meridian altitude, declination, amplitude, and setting of the sun and moon, &c. ——— 26 15 0

126 Orreries, which shew all the above phenomena, with the motion of the inferior planets only, or with the motions of all the superior planets and their satellites, with many improvements, are made by me at various prices, according to the intention or desire of the persons who propose to be purchasers, from 130 guineas, to — 1500 0 0

Smaller instruments of this kind, designed to shew only a few of the particular phenomena, are made at various prices.

		£	s.	d.
127	Aſtronomical quadrants, 3 feet radius —— ——	130	0	0
128	Ditto, 2 feet radius ——	70	0	0
129	Ditto, 18 inches radius —	50	0	0
130	Ditto, 12 inches radius —	31	10	0

And all other aſtronomical inſtruments, as ſectors for obſerving angular diſtances and differences in right aſcention, equal altitude inſtruments, and tranſit inſtruments, &c. of various prices according to their ſize, &c.

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		£	s.	d.
131	HADLEY's quadrant —	2	0	0
132	Ditto —— ——	2	12	6
133	Ditto —— ——	3	3	0
134	Ditto —— ——	4	4	0
135	Hadley's ſextant ——	8	8	0
136	Dr. Knight's ſteering compaſs	2	12	6
137	———— azimuth compaſs	5	15	6

Theſe with all ſorts of ſcales, rules, and all the inſtruments uſed in experiments of natural philoſophy, for mechanicks, pneumatics, hydroſtatics, &c. are made, when ordered, at moderate prices.

To

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To enumerate all the various articles that are uſed in making experiments, or for other purpoſes, would alone fill a volume. I have therefore ſelected the principal inſtruments in uſe, to moſt of which I have affixed prices and numbers, for the eaſe of thoſe Gentlemen and Ladies at any diſtance from London, who may have occaſion to write for any of the above inſtruments,

To their humble ſervant,

GEORGE ADAMS,

At No. 60. in Fleet-Street, LONDON.

The following BOOK, newly printed for the Author, may be had at his Houſe, No. 60, at *Tycho Brahe*'s Head, in Fleet-Street, and of the Bookſellers in Town and Country.