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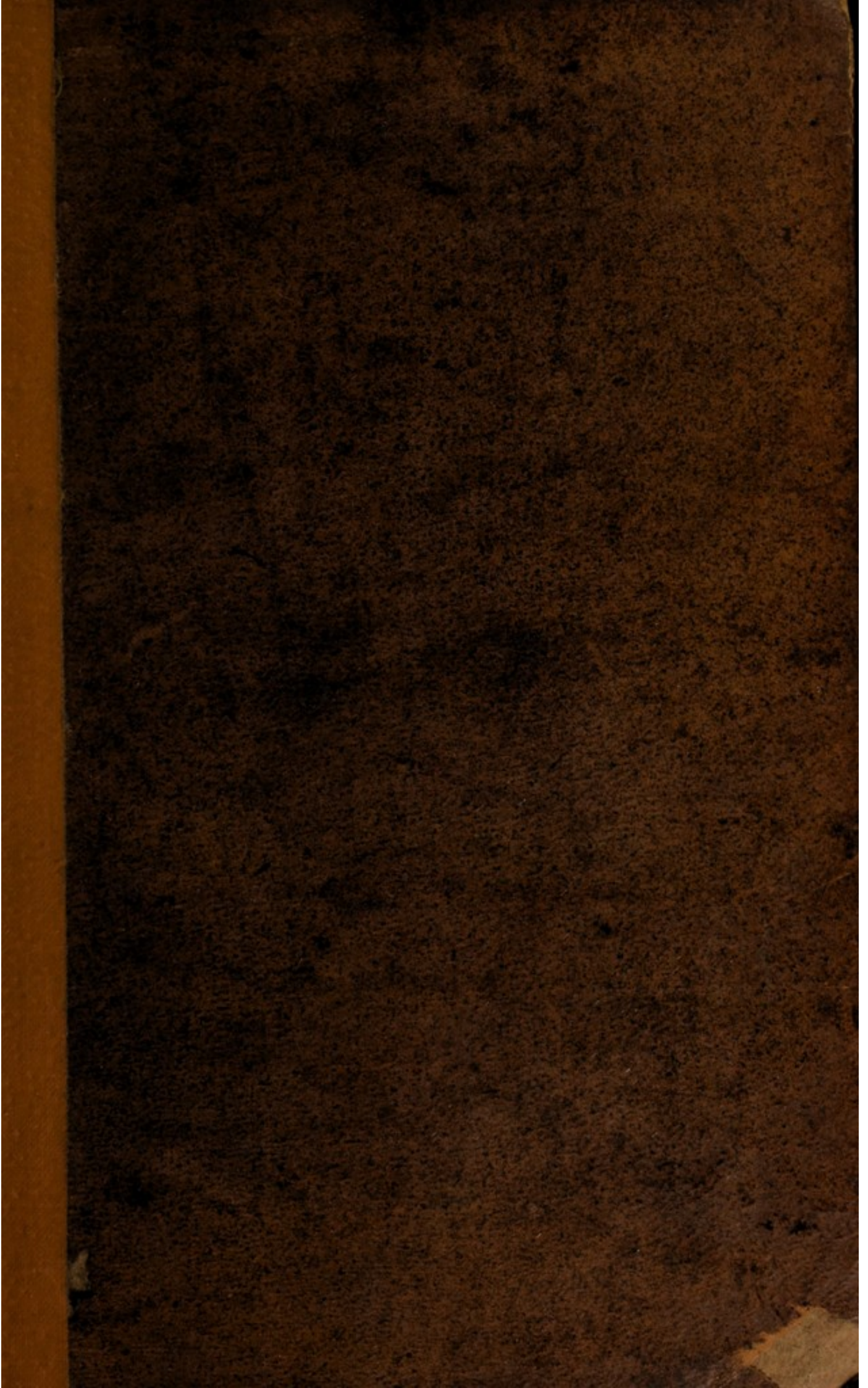
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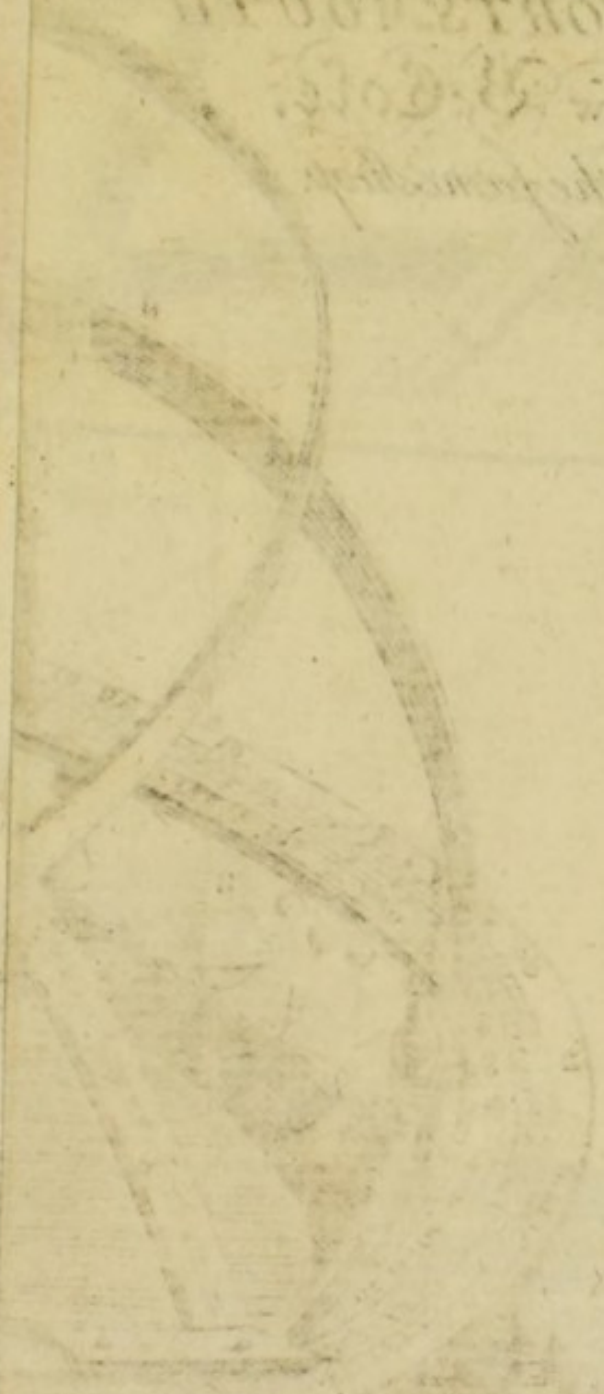
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THE
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 OF THE
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 AND THE
 O R R E R Y.

To which is prefix'd,

By Way of INTRODUCTION,

A brief Account of the SOLAR SYSTEM.

By JOSEPH HARRIS,
 TEACHER OF THE MATHEMATICS.

THE TWELFTH EDITION.

L O N D O N :

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ERRATA.

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THE
INTRODUCTION,

CONTAINING

A Brief Account of the SOLAR
SYSTEM, and of the FIXED
STARS.

SECT. I.

*Of the Order and Periods of the Primary
Planets revolving about the Sun; and
of the Secondary Planets round their
respective Primaries.*

THE Sun is placed in the midst
of an immense space, wherein
fix opaque spherical bodies re-
volve about him as their center. These
wandering globes are called the *Pla-Planets;*
nets, who, at different distances, and

B

in

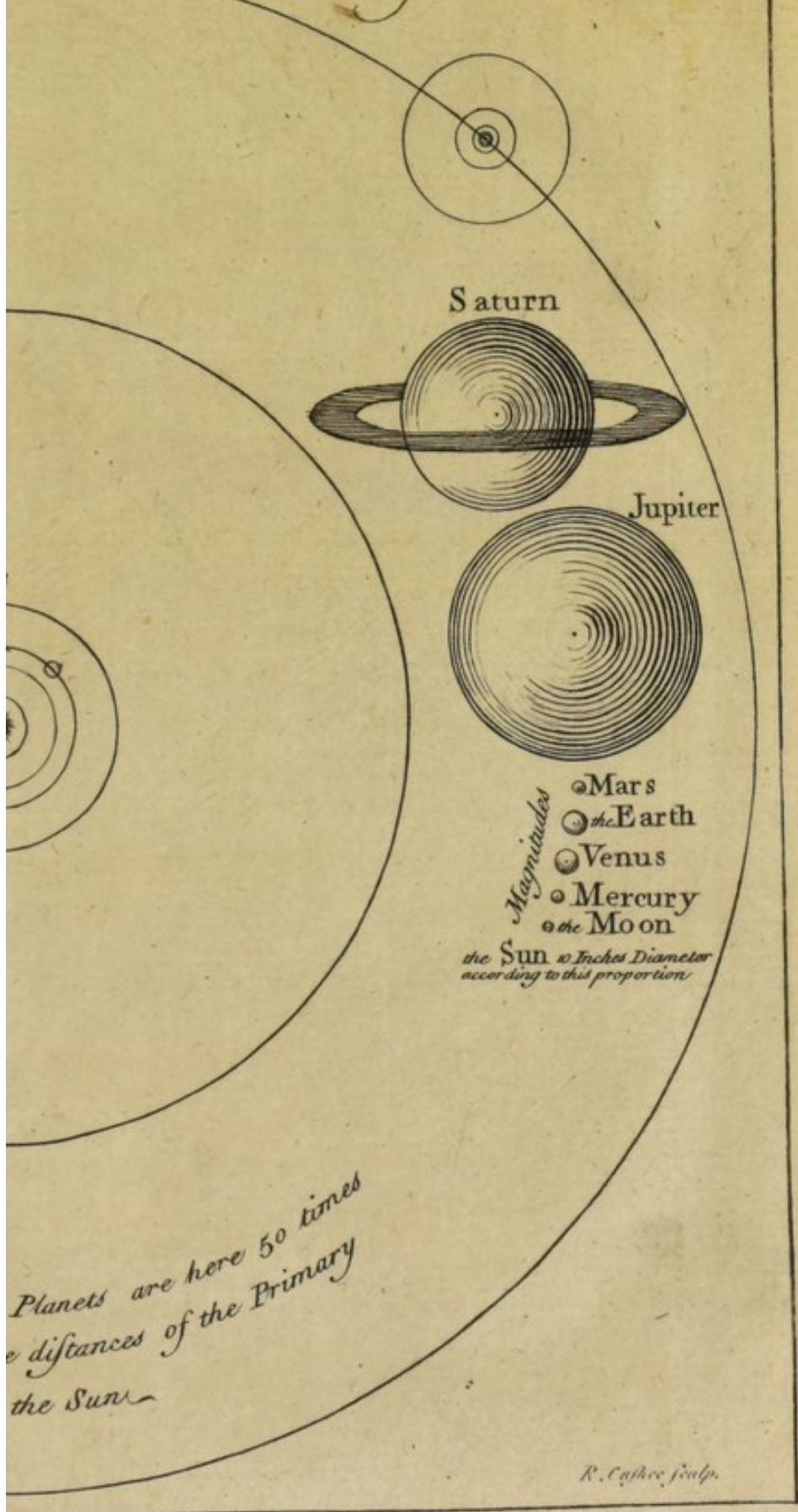
in different periods, perform their revolutions from West to East in the following order :

1. ☿ *Mercury* is nearest to the Sun of all the planets, and performs its course in about three months. 2. ♀ *Venus* in about seven months and a half. 3. ⊕ The *Earth* in a year. 4. ♂ *Mars* in about two years. 5. ♃ *Jupiter* in twelve. And lastly, ♄ *Saturn*, whose * *Orbit* includes all the rest, spends almost thirty years in one revolution round the Sun. The distances of the Planets from the Sun are nearly in the same proportion as they are represented in *Plate 1. viz.* Supposing the distance of the Earth from the Sun to be divided into 10 equal parts, that of *Mercury* will be about 4 of these parts; of *Venus* 7; of *Mars* 15; of *Jupiter* 52; and that of *Saturn* 95.

The

The Characters placed before the names of the Planets, are for brevity's sake commonly made use of by Astronomers, instead of the words at length, as ♀, for *Venus*, &c.

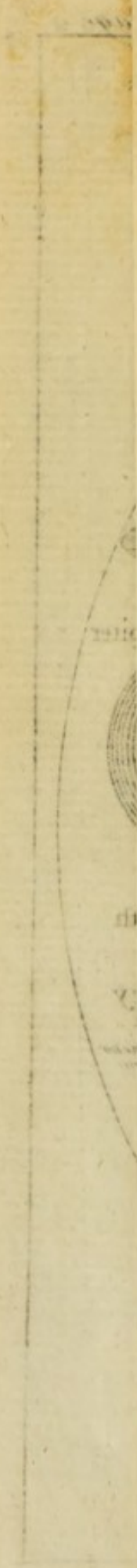
* By the Orbit of a Planet is commonly understood the Tract or Ring, described by its Center round the Sun, but by the Plane of the Orbit is meant a flat Surface extended every way through the Orbit infinitely.



*Planets are here 50 times
 the distances of the Primary
 the Sun*

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The orbits of the Planets are not all in the same plane, but variously inclined to one another; so that supposing one of them to coincide with the above scheme, the others will have one half above, and the other half below it, intersecting one another in a line passing through the Sun. The plane of the Earth's orbit is called the *Ecliptic*; and this the astronomers make the standard to which the planes of the other orbits are judged to incline. The right line passing through the Sun, and the common intersection of the plane of the orbit of any planet and the Ecliptic, is called the *Line of the Nodes* of that planet; *Nodes*; and the points themselves, wherein the orbit cuts the Ecliptic, are called the *Nodes*.

The inclinations of the orbits of the Planets to the plane of the ecliptic, are as follows, *viz.* the orbit of *Mercury* makes an angle with it of almost 7 degrees; that of *Venus* something above $3\frac{1}{2}$ degrees; of *Mars*, a little less than 2 degrees; of *Jupiter*, $1\frac{1}{2}$ degree; and of *Saturn*, about $2\frac{1}{2}$ degrees. The orbits of the Planets are not circles, but ellipses or ovals. What an ellipsis is, may be easily understood from the

following description. Imagine two small pegs fixed upright on any plane, and suppose them tied with the ends of a thread somewhat longer than their distance from one another: Now if a pin be placed in the double of the thread, and turned quite round (always stretching the thread with the same force) the curve described by this motion is an *Ellipsis*. The two points where the pegs stood (about which the thread was turned) are called the *foci* of that ellipsis; and if, without changing the length of the thread, we alter the position of the pegs, we shall then have an ellipsis of a different kind from the former; and the nearer the *focus's* are together, the nearer will the curve described be to a circle; until at last, the two *focus's* coincide, and then the pin in the doubling of the thread will describe a perfect circle. The orbits of all the Planets have the Sun in one of their *focus's*, and half the distance between the two *focus's* is called the *Excentricity* of the orbits. This excentricity is different in all the planets, but in most of them so small, that in little schemes or instruments, made to represent the planetary orbits, it need not be considered.

Excentricity.

The

The six Planets above-mentioned, are called *Primaries*, or *Primary Planets*; but besides these, there are ten other lesser Planets, which are called *Secondaries*, *Moons*, or *Satellites*. These moons always accompany their respective primaries, and perform their Revolutions round them, whilst both together are also carried round the Sun. Of the six Primary Planets, there are but three, as far as observation can assure us, that have these attendants, *viz.* the *Earth*, *Jupiter*, and *Saturn*.

The Earth is attended by the *Moon*, who performs her revolution in about $27\frac{1}{3}$ Days, at the distance of about 30 Diameters of the Earth from it; and once a year is carried round the Sun along with the Earth.

Jupiter has four *Moons*, or *Satellites*; the *first*, or innermost, performs its revolution in about one Day, and $18\frac{1}{2}$ Hours, at the distance of $5\frac{2}{3}$ Semidiameters of *Jupiter*, from his Center; the *second* revolves about *Jupiter* in 3 Days, 13 Hours, at the distance of 9 of his Semidiameters; the *third* in 7 Days, and 4 Hours, at the distance of $14\frac{1}{3}$ Semidiameters; the *fourth*, and outermost,

ermost, performs its course in the space of 16 Days, 18 Hours; and is distant from *Jupiter's* center $25\frac{1}{2}$ of his Semidiameters.

Saturn
has five
Moons.

Saturn has no less than five *Satellites*; the *first*, or innermost, revolves about him in 1 Day, and 21 Hours, at the distance of $4\frac{1}{2}$ Semidiameters of $\frac{1}{2}$, from his center; the *second* compleats his period in $2\frac{3}{4}$ Days, at the distance of $5\frac{5}{8}$ of his Semidiameters; the *third*, in about $4\frac{1}{2}$ Days, at the distance of $8\frac{1}{8}$ Semidiameters; the *fourth* performs its course in about 16 Days, at the distance of $18\frac{2}{3}$ Semidiameters; the *fifth* and outermost, takes $79\frac{1}{3}$ Days, to finish his course, and is 56 Semidiameters of *Saturn* distant from his center. The *Satellites*, as well as their primaries, perform their revolutions from *West* to *East*: The planes of the Orbits of the *Satellites* of the same Planet are variously inclined to one another, and consequently are inclined to the plane of the orbit of their primary.

Saturn's
Ring.

Besides these attendants, *Saturn* is encompassed with a thin plain Ring, that does no where touch his body: The diameter of this Ring is to the diameter of
of

of *Saturn* as 9 to 4; and the void space between the Ring and the body of *Saturn* is equal to the breadth of the Ring itself; so that in some situations the Heavens may be seen between the Ring and his body. This surprizing phænomenon of *Saturn's* Ring, is a modern discovery; neither were the Satellites of *Jupiter* and *Saturn* known to the ancients. The *Jovial* Planets were first discovered by the famous *Italian* philosopher *Galilæus*, by a telescope which he first invented; and the celebrated *Cassini*, the *French* king's astronomer, was the first that saw all the Satellites of *Saturn*; which by reason of their great distances from the Sun, and the smallness of their own bodies, cannot be seen by us, but by the help of very good glasses.

The motion of the primary Planets *Annual Motion.* round the Sun (as also of the Satellites round their respective primaries) is called their *Annual Motion*; because they have one Year, or alteration of Seasons compleat, in one of these revolutions. Besides this annual motion, four of the Planets, *viz. Venus, the Earth, Mars, and Jupiter* revolve about their own *Axis*, from *West to East*; and this is called their *Diurnal Motion.* For by this rotation, each

point of their surfaces is carried successively towards or from the Sun, who always illuminates the hemisphere which is next to him, the other remaining obscure; and while any place is in the hemisphere, illuminated by the Sun, it is *Day*, but when it is carried to the obscure hemisphere, it becomes *Night*; and so continues, until by this rotation the said place is again enlightened by the Sun.

Diurnal
Motion of
the \oplus , \ominus ,
 $\♃$ and $\♄$.

\odot and D
likewise
turn
round
their Axis

The *Earth* performs its revolution round its axis in 23 Hours, 56 Minutes; * *Venus* in 24 Days, 8 Hours; *Mars* in 24 Hours, and 40 Minutes; and *Jupiter* moves round his own axis in 9 Hours, and 56 Minutes. The Sun also is found to turn round his axis from West to East, in about 26 Days: And the Moon, which is nearest to us of all the Planets, revolves about her axis in a month, or in the same space of time that she turns round

* N. B. According to *Bianchini's* Observations, *Venus's* axis inclines 75 degrees from the perpendicular to the plane of the Ecliptic (which is $51\frac{1}{2}$ deg. more than the axis of our Earth) her Tropics are only 15 deg. from her Poles, and her Polar Circles at the same distance from her *Equator*; so that the Sun's greatest Declination on each side of her *Equator* is 75 deg. by which she must undergo a much greater variety of seasons than we do on our Earth.

round the Earth; so that the *Lunarians* have but 1 Day throughout the Year.

I. The Planets are all *Opaque* bodies, having no light but what they borrow from the Sun; for that side of them which is next towards the Sun, has always been observed to be illuminated, in what position soever they be; but the opposite side, which the Solar rays do not reach, remains dark and obscure; whence it is evident, that they have no light but what proceeds from the Sun; for if they had, all parts of them would be lucid, without any darkness or shadow. The Planets are likewise proved to be *Globular*; because let what part soever of them be turned towards the Sun, its boundary, or the line separating that part from the opposite, always appears to be circular; which could not happen, if they were not globular.

The Planets are Opaque and Globular.

II. That the Earth is placed betwixt the Orbs of *Mars* and *Venus*, and that $\text{\textcircled{♃}}$, $\text{\textcircled{♀}}$, $\text{\textcircled{♁}}$, $\text{\textcircled{♂}}$, and $\text{\textcircled{♄}}$, do all turn round the Sun, is proved from observations as follow:

The Planets turn round the Sun,

1. Whenever *Venus* is in conjunction with the Sun, that is, when she is in the same

same direction from the Earth, or towards the same part of the Heavens the Sun is in; she either appears with a bright and round face, like a full Moon, or else disappears: Or, if she is visible, she appears horned, like a new Moon; which phænomena could never happen if ♀ did not turn round the Sun, and was not betwixt him and the Earth: For since all the Planets borrow their light from the Sun, it is necessary that ♀'s lucid face should be towards the Sun; and when she appears fully illuminated, she shews the same face to the Sun and Earth; and at that time she must be above or beyond the Sun; for in no other position could her illuminated face be seen from the Earth. Farther, when she disappears, or if visible, appears horned, that face of her's which is towards the Sun is either wholly turned from the Earth, or only a small part of it can be seen by the Earth; and in this case she must of necessity be betwixt us and the Sun. Let S be the *Sun*, T the *Earth*, and V *Venus*, having the same face presented both towards the *Sun* and *Earth*; here it is plain that the Sun is betwixt us and *Venus*, and therefore we must either place *Venus* in an Orbit round the Sun, and likewise betwixt him
and

Plate 2.
Fig. 1, 2.

and us, as in *Fig. 1.* or else we must make the Sun to move round the Earth in an Orbit within that of *Venus*, as in *Fig. 2.* Again, after *Venus* disappears, or becomes horned, at her * ζ with the \odot , she must then be betwixt us and the Sun, and must move either in an Orbit round the Sun, and betwixt us and him, as in *Fig. 1.* or else round the Earth, and betwixt us and the Sun, as in *Fig. 2.* But *Venus* cannot move sometimes within the Sun's Orbit, and sometimes without it, as we must suppose if she moves round the Earth; therefore it is plain that her motion is round the Sun.

Besides the foregoing, there is another argument to prove that *Venus* turns round the Sun in an Orbit that is within the Earth's, because she is always observed to keep near the Sun, and in the same quarter of the Heavens that he is in, never receding from him more than about $\frac{1}{3}$ of a whole circle; and therefore she can never come in opposition to him; which would necessarily happen, did she perform her course round the Earth either in a longer or shorter time than a Year. And this is the reason

* ζ Is a mark commonly used for conjunction: thus ζ with the \odot , is to be read conjunction with the Sun.

Why *Venus* is always either our Morning or Evening Star.

reason why *Venus* is never to be seen near midnight, but always either in the Morning or Evening, and at most not above three or four Hours before Sun-rising or after Sun-setting. From the time of ♀'s superior conjunction (or when she is above the Sun) she is more Easterly than the Sun, and therefore sets later, and is seen after Sun-setting; and then she is commonly called the *Evening Star*. But from the time of her inferior conjunction, till she comes again to the superior, she then appears more Westerly than the Sun, and is only to be seen in the morning before Sun-rising, and is then called the *Morning Star*.

After the same manner we prove that *Mercury* turns round the Sun, for he always keeps in the Sun's neighbourhood, and never recedes from him so far as *Venus* does; and therefore the Orbit of ☿ must lie within that of ♀; and on the account of his nearness to the Sun, he can seldom be seen without a Telescope.

The Orbit of *Mars* includes the Earth's.

Mars is observed to come in opposition, and likewise to have all other aspects with the Sun; he always preserves a round,

a round, full, and bright face, except when he is near his quadrature aspect, when he appears somewhat gibbous, like the Moon three or four Days before or after the full: Therefore the Orbit of $\text{\textcircled{♂}}$ must include the Earth within it, and also the Sun; for if he was betwixt the Sun and us at the time of his inferior conjunction, he would either quite disappear, or appear horned, as *Venus* and the Moon do in that position.

Let S be the *Sun*, T the *Earth*, and *Fig. 3.*

A P *Mars*, both in his conjunction and opposition to the Sun, and in both positions full; and B C *Mars* at his quadratures, when he appears somewhat gibbous from the Earth at T. 'Tis plain hence, that the Orbit of *Mars* does include the Earth, otherwise he could not come in opposition to the Sun; and that it likewise includes the Sun, else he could not appear full at his conjunction.

Mars when he is in opposition to the Sun, looks almost seven times larger in diameter than when he is in conjunction with him, and therefore must needs be almost seven times nearer to us in one position than in the other; for the apparent magnitudes of far distant

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distant objects increase or decrease in proportion to their distances from us ; But *Mars* keeps always nearly at the same distance from the Sun ; therefore it is plain that it is not the Earth, but the Sun, that is the center of his motion.

It is proved in the same way, that *Jupiter* and *Saturn* have both the Sun and the Earth within their Orbits, and that the Sun, and not the Earth, is the center of their motions ; altho' the disproportion of the distances from the Earth is not so great in *Jupiter*, as it is in *Mars*, nor so great in *Saturn*, as it is in *Jupiter*, by reason that they are at a much greater distance from the Sun.

*Inferior
and Super-
rior Pla-
nets.*

We have now shewn that all the Planets turn round the Sun, and that *Mercury* and *Venus* are included between him and the Earth, whence they are called the *Inferior Planets*, and that the Earth is placed between the Orbits of *Mars* and *Venus*, and therefore included within the Orbits of *Mars*, *Jupiter*, and *Saturn*, whence they are called the *Superior Planets* : And since the Earth is in the middle of these moveable bodies, and is of the same nature with them,

we

we may conclude that she has the same sort of motions; but that she turns round the Sun is proved thus:

All the Planets seen from the Earth appear to move very unequally, sometimes to go faster, at other times slower; sometimes to go backwards, and sometimes to be stationary, or not to move at all; which could not happen if the Earth stood still. Let S be the Sun, T the Earth, the great circle ABCD the Orbit of *Mars*, and the numbers 1, 2, 3, &c. its equable motion round the Sun; the correspondent numbers 1, 2, 3, &c. in the circle *a, b, c, d*, the motion of *Mars*, as it would be seen from the Earth. It is plain from this Figure, that if the Earth stood still, the Motion of *Mars*, will be always progressive, (tho' sometimes very unequal;) but since observations prove the contrary, it necessarily follows, that the Earth turns round the Sun.

The earth does not stand still, but turns round the Sun.

Fig. 4.

The annual periods of the Planets round the Sun are determined by carefully observing the length of time since their departure from a certain point in the Heavens, (or from a fix'd Star) until they arrive to the same again.

The Annual and Diurnal Motions of the Planets, how computed.

By

By these sort of observations the ancients determined the periodical revolutions of the Planets round the Sun, and were so exact in their computations, as to be capable of predicting Eclipses of the Sun and Moon. But since the invention of telescopes, astronomical observations are made with greater accuracy; and of consequence, our tables are far more perfect than those of the ancients. And in order to be as exact as possible, astronomers compare observations made at a great distance of time from one another, including several periods; by which means, the error that might be in the whole, is in each period subdivided into such little parts as to be inconsiderable. Thus the mean length of a Solar Year is known, even to Seconds.

The Diurnal rotation of the Planets round their axis, was discovered by certain spots which appear on the surfaces. These spots appear first in the margin of the Planet's disk, (or the edge of their surfaces) and seem by degrees to creep toward their middle, and so on, going still forward, 'till they come to the opposite side or edge of the disk, where they set, or disappear; and

and after they have been hid for the same space of time, that they were visible, they again appear to rise in or near the same place, as they did at first, then to creep on progressively, taking the same course as they did before. These spots have been observed on the surfaces of the *Sun*, *Venus*, *Mars*, and *Jupiter*; by which means it has been found that these bodies turn round their own axis, in the times before-mentioned. It is very probable that *Mercury* and *Saturn* have likewise a motion round their axis, that all the parts of their surface may alternately enjoy the light and heat of the Sun, and receive such changes as are proper and convenient for their nature. But by reason of the nearness of $\text{\textcircled{v}}$ to the Sun, and $\text{\textcircled{h}}$'s immense distance from him, no observations have been hitherto made whereby their spots (if they have any) could be discovered, and therefore their Diurnal motions could not be determined. The Diurnal motion of the Earth is computed from the apparent revolution of the Heavens, and of all the Stars round it, in the space of a natural Day. The Solar spots do not always remain the same, but sometimes old ones vanish, and afterwards others succeed in their
C room;

room; sometimes several small ones gather together and make one large spot, and sometimes a large spot is seen to be divided into many small ones. But, notwithstanding these changes, they all turn round with the Sun in the same time.

How the relative distances of the Planets from the Sun are determined.

The relative distances of the Planets from the Sun, and likewise from each other, are determined by the following methods: First, the distance of the two inferior Planets ☿ and ♀ from the Sun, in respect of the Earth's distance from him, is had by observing their greatest Elongation from the Sun as they are seen from the Earth.

Fig. 5.
Elongation.

The greatest *Elongation* of *Venus* is found by observation to be about 48 degrees, which is the angle $S T \text{♀}$; whence, by the known rules of Trigonometry, the proportion of $S \text{♀}$, the mean distance of *Venus* from the Sun to $S T$, the mean distance of the Earth from him may be easily found. After the same manner, in the right-angled triangle $S T \text{♁}$, may be found the distance $S \text{♁}$ of *Mercury* from the Sun. And if the mean distance of the Earth from the Sun $S T$ be made 1000, the mean distance of *Venus* $S \text{♀}$ from the Sun

Sun will be 723 ; and of *Mercury* 58, 387 : And if the Planets moved round the Sun in circles, having him for their center, the distances here found would be always their true distances : But as they move in Ellipses, their distances from the Sun will be sometimes greater, and sometimes less. Their *Excentricities* are computed to be as follows, *viz.*

Excent. of $\left\{ \begin{array}{l} \text{Mercury} \quad 80 \\ \text{Venus} \quad \quad 5 \\ \text{Earth} \quad 16,9 \end{array} \right\}$ of the parts above-mentioned.

The distances of the superior Planets, *viz.* δ , ψ , and η , are found by comparing their true places, as they are seen from the Sun, with their apparent places, as they are seen from the Earth. Let S be the Sun, the circle ABC the Earth's orbit, A G a line touching the Earth's orbit, in which we'll suppose the superior Planets are seen from the Earth in the points of their orbits δ , ψ , η ; and let D E F G be a portion of a great circle in the Heavens, at an infinite distance : Then the place of *Mars* seen from the Sun is D, which is called his true, or *Heliocentric Place* ; but from the Earth, he will be seen in G, which is called his apparent, or

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Geocentric Place. So likewise *Jupiter* and *Saturn* will be seen from the Sun in the points E and F, their Heliocentric places; but a spectator from the Earth will see them in the point of the Heavens G, which is their Geocentric place. The arches DG, EG, FG, the differences between the true and apparent places of the superior Planets, are called the *Parallaxes* of the Earth's annual Orb, as seen from these Planets. If thro' the Sun we draw SH parallel to AG, the angles $A \delta S$, $A \gamma S$, $A \epsilon S$, will be respectively equal to the angles DSH, ESH, and FSH; and the angle AGS is equal to the angle GSH, whose measure is the arch GH; which therefore will be the measure of the angle AGS, the angle under which the semidiameter AS of the Earth's orbit, is seen from the Starry Heavens. But this semidiameter is nothing in respect of the immense distance of the Heavens or Fixed Stars; for from thence it would appear under no sensible angle, but look like a point. And therefore in the Heavens, the angle GSH, or the arch GH vanishes; and the Points G and H coincide; and the arches DH, EH, FH, may be considered as being of the same bigness with

with the arches $D G$, $E G$, and $F G$, which are the measures of the angles $A \delta S$, $A \gamma S$, $A \eta S$; which angles are nearly the greatest elongation of the Earth from the Sun, if the Earth be observed from the respective Planets, when the line $G \eta \gamma \delta A$, touches the Earth's orbit in A . The nearer any of the superior Planets is to the Sun, the greater is the Parallax of the annual Orb, or the angle under which the semidiameter of the Earth's orbit is seen from that Planet. In *Mars* the angle $A \delta S$, (which is the visible enlongation of the Earth seen from *Mars*, or the Parallax of the annual Orb seen from that Planet) is about 42 degrees, and therefore the Earth is always to the inhabitants of *Mars* either their Morning or Evening Star, and is never seen by them so far distant from the Sun as we see *Venus*. The greatest elongation of the Earth seen from *Jupiter*, being nearly equal to the angle $A \gamma S$, is about 11 degrees. In *Saturn* the angle $A \eta S$ is but 6 degrees, which is not much above $\frac{1}{4}$ part of the greatest elongation we observe in *Mercury*. And since *Mercury* is so rarely seen by us, probably the astronomers of *Saturn* (except they have better Optics than we have) have not yet

discovered that there is such a body as our Earth in the Universe.

The Parallax of the annual Orb, or the greatest elongation of the Earth's orbit seen from any of the superior Planets, being given; the distance of that Planet from the Sun, in respect of the Earth's distance from him, may be found by the same methods as the distances of the inferior Planets were. Thus, to find the distance of *Mars* from the Sun, it will be as the Sine of the angle $S \delta A$ is to the *Radius*, so is the distance $A S$ (the distance of the Earth from the Sun) to $S \delta$, the distance from the Sun to *Mars*. After the same manner the distances of *Jupiter* and *Saturn* are also found. The mean distance of the Earth from the Sun being made 1000, the mean distances of the superior Planets from the Sun are, *viz*, the mean distance from the Sun of

$$\left\{ \begin{array}{l} \delta \quad 1524 \\ 4 \quad 5201 \\ \nu \quad 9540 \end{array} \right\} \text{and the Excentricity} \left\{ \begin{array}{l} 141 \\ 250 \\ 547 \end{array} \right\}$$

To which, if you add or subtract their mean distances, we shall have the greatest or least distances of those Planets from the Sun.

There

There are other methods by which the relative distances of the Planets might be found; but that which hath been here illustrated, is sufficient to evince the certainty of that Problem.

Hitherto we have only considered the distances of the Planets in relation to one another, without determining them by any known measure; but in order to find their absolute distances in some determinate measure, there must be something given, whose measure is known. Now the circumference of the Earth is divided into 360 degrees, and each of these degrees into 60 Geographical miles, so that the whole circumference contains 21600; and by the known proportion for finding the diameter of a circle from its circumference, the Earth's diameter will be found to be 6872 miles, and its semidiameter 3436 miles. The Parallax of the Earth's semidiameter, or the angle under which it is seen from a certain Planet, may be found by comparing the true place of the Planet, as it would be seen from the center of the Earth (which is known by computation) with its apparent place, as it is seen from some point on the Earth's surface. Let CZA be the Earth, ZC its

How the absolute distances of the Planets from the Sun are computed.

Parallax of the Earth's Semidiameter.

Fig. 7.

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semidiameter, \oplus some Planet, and BHT arch of a great circle in the Heavens, at an infinite distance. Now the Planet \oplus will appear from the Earth's center C, in the point of the Heavens H; but a spectator from the point Z upon the Earth's surface, will see the same object \oplus in the point of the Heavens B; and the arch BH the difference, is equal to the angle $B \oplus H = Z \oplus C$, the *Parallax*; which being known, the side C \oplus the distance of the Planet from the center of the Earth, at that time, may be easily found. Now if this distance of the Planet from the Earth be determined, when the centers of the Sun, the said Planet, and of the Earth, are in the same right line, we have the absolute distance of the Planet's orbit from the Earth's in known measure; then it will be, as the relative distance betwixt the Earth's orbit and that of the Planet is to the relative distance of the said Planet from the Sun; so is the distance of the Planet's orbit from the Earth's in known measure to the distance of the said Planet from the Sun in the same measure: Which being known, the distance of all the other Planets from the Sun may be found. For it will be, as the relative distance of any Planet from the Sun, is
to

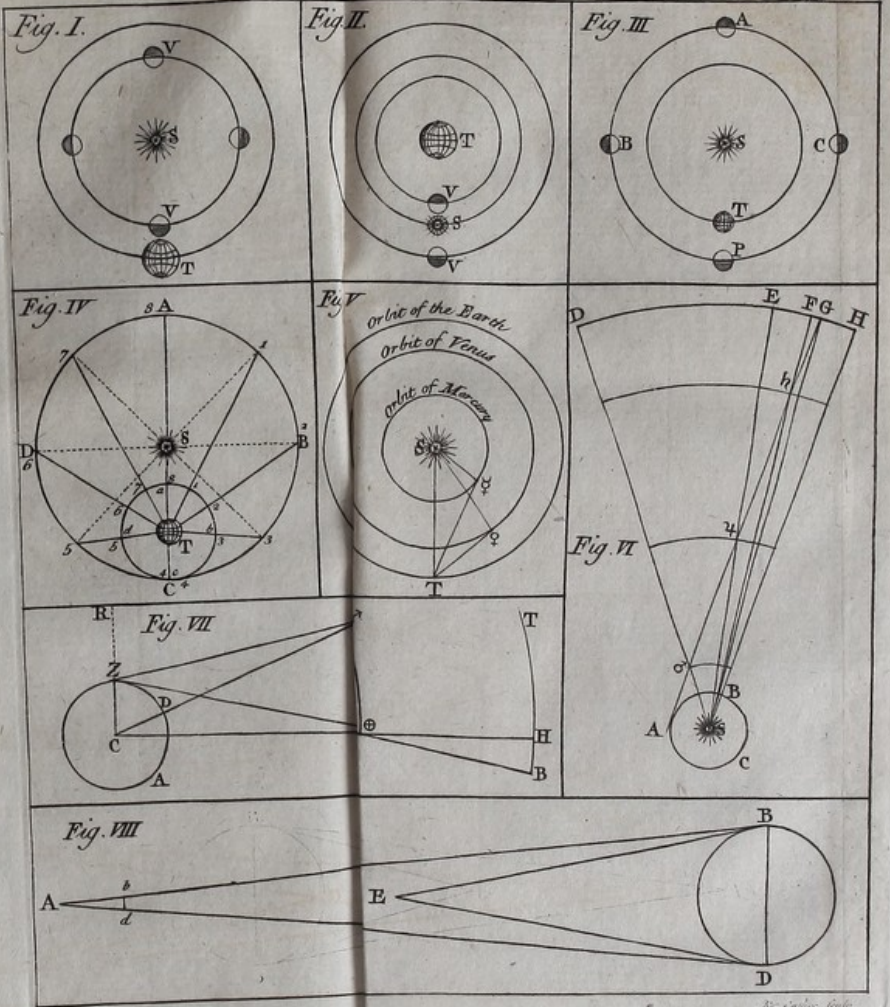
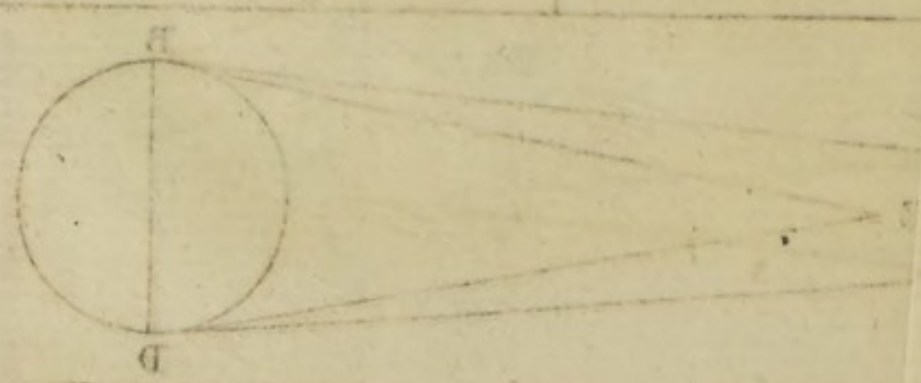
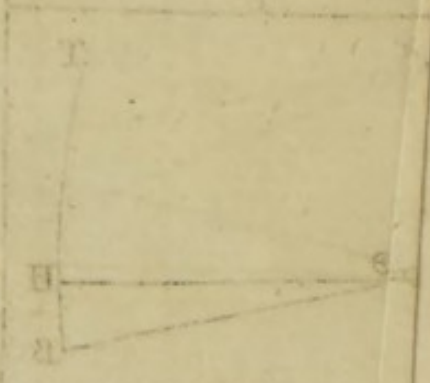
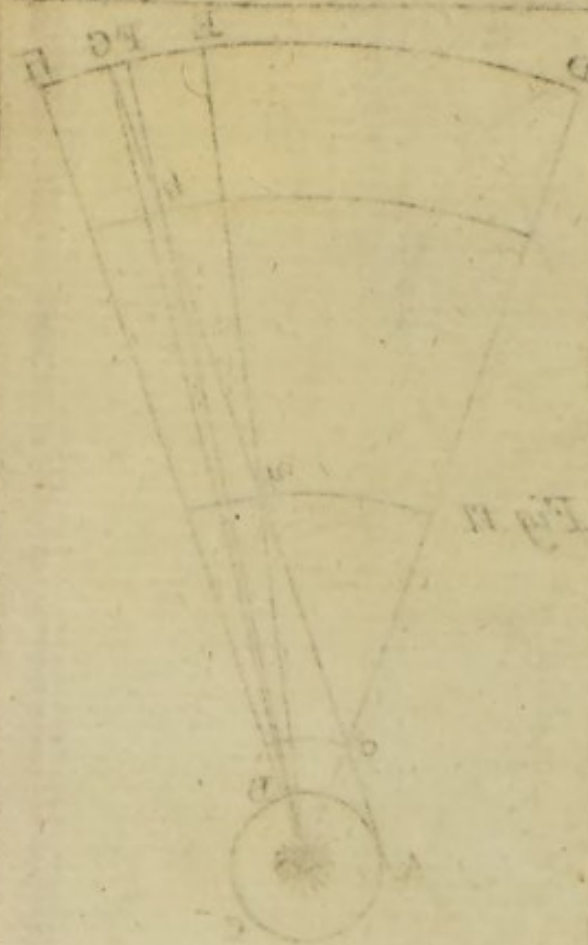
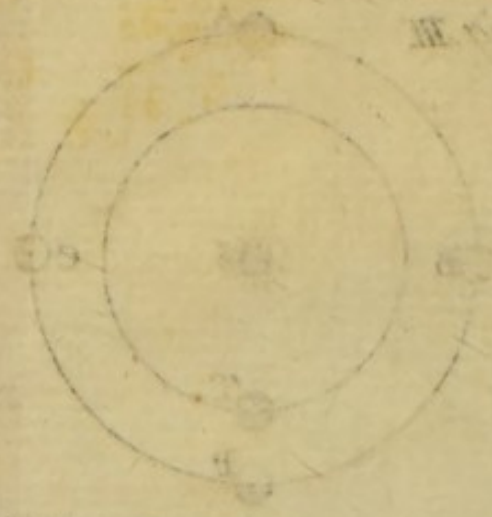


Fig III



to its distance from him in a known measure; so is the relative distance of any other Planet from him to its distance in the same measure. This may be done by finding the distance of the Planet *Mars*, when he is in opposition to the Sun, after the same manner as we find the distance of a tree, or the like, by two stations.

Let δ be *Mars*, D the point on the Earth's superficies, where *Mars* is vertical when he is in opposition to the Sun, which may be found exactly enough by calculation, at which time let an observer, at the point Z (whose situation from D must be known) take the altitude of *Mars*, whose complement will be the angle δ Z R; then in the triangle δ Z C will be given the angle δ Z C, the angle C (whose measure is the arch DZ) and consequently the angle Z δ C the Parallax, and also the side Z C the semidiameter of the Earth; by which we may find C δ the distance of *Mars* from the Earth. The extreme nicety required in this observation, makes it very difficult to determine the exact distances of the Planets from the Sun; but the celebrated Dr. *Halley* has, in the *Philosophical Transactions*, shewed us a more cer-

certain method for finding the distances of the Planets; which is, by observing the Transit of *Venus* over the Sun.

How the
Magni-
tudes of
the Pla-
nets are
determin-
ed.

Fig. 8.

The eye judgeth of the magnitudes of far distant objects, according to the quantities of the angles under which they are seen (which are called their apparent magnitudes;) and these angles appear greater or less in a certain proportion to their distances. Wherefore the distances of the Planets from the Earth, and their apparent diameters being given, their true diameters (and from thence their magnitudes) may be found. How the distances of the Planets may be found has been already shewn; their apparent diameters are found by a telescope, having a machine fixed to it for measuring of angles, called a Micrometer. Let BD , or the angle BAD , be the apparent diameter of any Planet, and AB , or AD , (which by reason of the great distance of the Planets in respect of their magnitudes) may be considered as being the distance of the said Planet from the observer. Now in the triangle ABD , having the sides AB , AD , given, and the angle A , we have also the other angles B and D (because the sides AB , AD , are equal) whence the side

side BD the diameter of the Planet may be easily found by Trigonometry.

From hence it appears, that the same body at different distances, will seem to have very different magnitudes. Thus the diameter BD will appear from the point E, to be twice as large as from the point A. It also follows, that a small body, when at no great distance from us, may appear to be equal, or even to exceed another at a greater distance, though immensely bigger. Thus *bd* appears under the same angle, and consequently of the same bigness from the point A, that the line BD doth, though one vastly exceeds the other. And this is the reason why the Moon, which is much less than any of the Planets, appears to us vastly bigger than either of them, and even to equal the Sun himself, which is many thousand times greater in magnitude.

Why the Moon appears bigger than any of the Planets.

The distances of the Planets, and periods round the Sun, their diameters and velocities round their own axis, according to modern computations, are as follows :

Saturn

	Y. D. H.	Distance in Miles.
<i>Saturn</i>	29:167:22	777.000.000
<i>Jupiter</i>	11:314:12	424.000.000
<i>Mars</i>	1:321:23	123.000.000
<i>Earth</i>	0:365:6	81.000.000
<i>Venus</i>	0:224:16	59.060.000
<i>Mercury</i>	0:87:23	32.000.000

Revolves about the Sun in the Space of

<i>Moon</i>	Round the Earth	D.H.M.	240:000
		27:7:43	

	Periods round their own axes.	Diameters in English Miles.
	D. H. M.	
<i>Sun</i>	25 : 6 : 0	763.000
<i>Saturn</i>	61.000
<i>Jupiter</i>	0 : 9 : 56	81.000
<i>Mars</i>	1 : 0 : 40	4.440
<i>Earth</i>	0 : 23 : 56	7.970
<i>Venus</i>	24 : 8 : 0	7.900
<i>Mercury</i>	4.240
<i>Moon</i>	27 : 7 : 43	2.170

The cause of *Eclipses* and *Phases* of the Moon, and some other phænomena not here explained, shall be shewed when we come to give a Description of the *Orrery*.

Besides the Planets already mentioned, there are other great bodies that sometimes visit our system, which are a sort of temporary Planets; for they come and abide with us for a while, and afterwards withdraw from us, for a certain space of time, after which they again return. These wandering bodies are called *Comets*.

The motion of *Comets* in the Hea- Of Comets
vens, according to the best observations hitherto made, seem to be regulated by the same immutable law that rules the Planets; for their orbits are elliptical, like those of the Planets, but vastly narrower, or more excentric. Yet they have not all the same direction with the Planets, who move from West to East, for some of the *Comets* move from East to West; and their orbits have different inclinations to the Earth's orbit; some inclining Northwardly, others Southwardly, much more than any of the Planetary orbits do.

Altho' both the *Comets* and the Planets move in elliptic orbits, yet their motions seem to be vastly different: For the excentricities of the Planet's orbits are so small, that they differ but little
from

from circles ; but the excentricities of the Comets are so very great, that the motions of some of them seem to be almost in right lines, tending directly towards the Sun.

Now, since the orbits of the Comets are so extremely excentric, their motions, when they are in their *Perihelia*, or nearest distance from the Sun, must be much swifter than when they are in their *Aphelia*, or farthest distance from him ; which is the reason why the Comets make so short a stay in our system ; and when they disappear, are so long in returning.

The figures of the Comets are observed to be very different ; some of them send forth small beams, like hair, every way round them ; others are seen with a long fiery tail, which is always opposite to the Sun. Their magnitudes are also very different, but in what proportion they exceed each other, it is as yet uncertain. Nor is it probable, that their numbers are yet known, for they have not been observed with due care, nor their theories discovered, but of late years. The ancients were divided in their opinions concerning them ; some ima-

imagined that they were only a kind of *Meteors* kindled in our atmosphere, and were there again diffipated; others took them to be some ominous prodigies: But modern discoveries prove, that they are Worlds subject to the same laws of motion as the Planets are; and they must be very hard and durable bodies, else they could not bear the vast heat that some of them, when they are in their *Peribelia*, received from the Sun, without being utterly consumed. The great Comet which appeared in the year 1680, was within $\frac{1}{8}$ part of the Sun's diameter from his surface; and therefore its heat must be prodigiously intense beyond imagination. And when it is at its greatest distance from the Sun, the cold must be as rigid.

S E C T.

S E C T. II.

Of the FIXED STARS.

The fixed stars are at immense distance from us.

THE fixed Stars are those bright and shining bodies, which in a clear night appear to us every where dispersed through the boundless regions of space. They are termed fixed, because they are found to keep the same immutable distance one from another in all ages, without having any of the motions observed in the Planets. The fixed Stars are all placed at such immense distances from us, that the best of telescopes represent them no bigger than points, without having any apparent diameters.

The fixed Stars are luminous bodies like the Sun.

It is evident from hence, that all the Stars are luminous bodies, and shine with their own proper and native light, else they could not be seen at such a great distance. For the *Satellites* of *Jupiter* and *Saturn*, tho' they appear under considerable angles through good tele-

telescopes, yet are altogether invisible to the naked eye.

Although the distance betwixt us and the Sun is vastly large, when compared to the diameter of the Earth, yet it is nothing when compared with the prodigious distance of the fixed Stars; for the whole diameter of the Earth's annual orbit, appears from the nearest fixed Star no bigger than a point, and the fixed Stars are at least 100,000 times farther from us than we are from the Sun; as may be demonstrated from the observation of those who have endeavoured to find the Parallax of the Earth's annual Orb, or the angle under which the Earth's orbit appears from the fixed Stars.

The distance from us to the Sun is nothing in comparison of the vast distance of the fixed Stars.

Hence it follows, that tho' we approach nearer to some fixed Stars at one time of the year than we do at the opposite, and that by the whole length of the diameter of the Earth's orbit; yet this distance being so small in comparison with the distance of the fixed Stars, their magnitudes or positions cannot thereby be sensibly altered; therefore we may always, without error, suppose ourselves to be in the same center

As to appearance, the Earth may be consider'd as being the center of the Heavens.

D of

The INTRODUCTION.

of the Heavens, since we always have the same visible prospect of the Stars without any alteration.

If a spectator was placed as near to any fixed Star, as we are to the Sun, he would there observe a body as big, and every way like, as the Sun appears to us : and our Sun would appear to him no bigger than a fixed Star : and undoubtedly he would reckon the Sun as one of them in numbering the Stars. Wherefore since the Sun differeth nothing from a fixed Star, the fixed Stars may be reckoned so many Suns.

The fixed Stars are Suns.

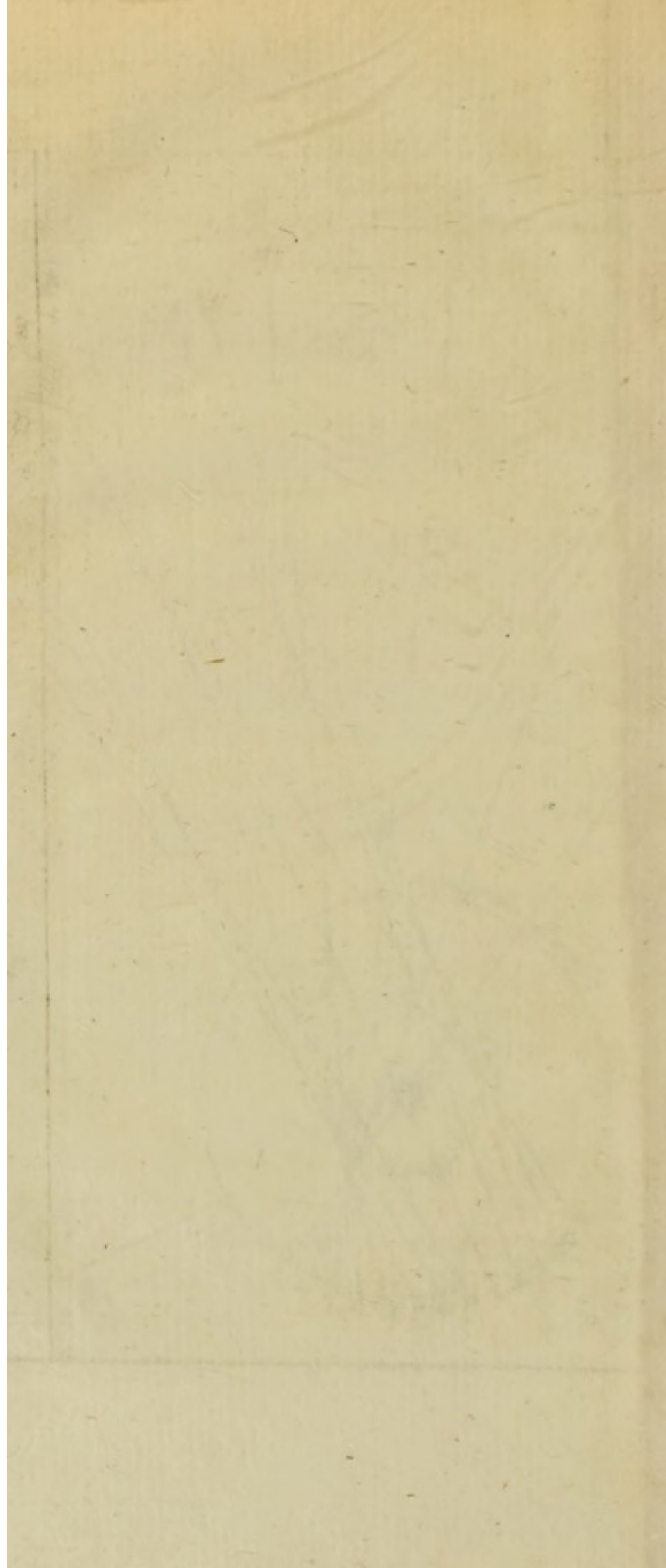
It is not reasonable to suppose that all the fixed Stars are placed at the same distance from us ; but it is more probable that they are every where interspersed thro' the vast indefinite space of the universe ; and that there may be as great a distance betwixt any two of them as there is betwixt our Sun and the nearest fixed Star. Hence it follows, why they appear to us of different magnitudes, not because they really are so, but because they are at different distances from us ; those that are nearest excelling in brightness and lustre those that are most remote, who give a faint-

The fixed Stars are at vast distances from each other.



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er light, and appear smaller to the eye.

The astronomers distribute the Stars into several orders or classes; those that are nearest to us, and appear brightest to the eye, are called Stars of the first magnitude; those that are nearest to them in brightness and lustre, are called Stars of the second magnitude; those of the third class, are stiled Stars of the third magnitude; and so on, until we come to the Stars of the sixth magnitude, which are the smallest that can be discerned by the naked eye. There are infinite numbers of smaller Stars, that can be seen through telescopes; but these are not reduced to any of the six orders, and are only called *Telescopical Stars*. It may be here observed, that tho' the astronomers have reduced all the Stars that are visible to the naked eye, into some one or other of these classes, yet we are not to conclude from thence, that all the Stars answer exactly to some or other of these orders; but there may be in reality as many orders of the Stars, as they are in number, few of them appearing exactly of the same bigness and lustre.

The distribution of the Stars into 6 classes.

Of Telescopical Stars.

The ancient astronomers, that they might distinguish the Stars, in regard to their situation and position to each other, divided the whole starry firmament into several *Asterisms*, or systems of Stars, consisting of those that are near to one another. These *Asterisms* are called *Constellations*, and are digested into the forms of some animals; as Men, Lions, Bears, Serpents, &c. or to the images of some known things; as, of a Crown, a Harp, a Triangle, &c.

The Stars
digested
into con-
stellations

The starry firmament was divided by the ancients into 48 images, or constellations; twelve of which they placed in that part of the Heavens wherein are the planes of the Planetary orbits; which part is called the *Zodiac*, because most of the constellations placed therein resemble some living creature. The two regions of the Heavens that are on each side of the *Zodiac*, are called the North and South parts of the Heavens.

Zodiac.

Constel-
lations
within the
Zodiac.

The constellations within the *Zodiac* are, 1. *Aries*, the *Ram*; 2. *Taurus*, the *Bull*; 3. *Gemini*, the *Twins*; 4. *Cancer*, the *Crab*; 5. *Leo*, the *Lion*; 6. *Virgo*, the *Virgin*; 7. *Libra*, the *Balance*; 8. *Scorpio*, the *Scorpion*; 9. *Sagitta-*

gittarius, the *Archer*; 10. *Capricornus*, the *Goat*; 11. *Aquarius*, the *Water-Bearer*; and, 12. *Pisces*, the *Fishes*.

The constellations on the North side of the *Zodiac* are Twenty-one, viz. Northern constellations. the *Little Bear*; the *Great Bear*; the *Dragon*; *Cepheus*, a king of *Ethiopia*; *Bootes*, the keeper of the *Bear*; the *Northern Crown*; *Hercules* with his *Club*, watching the *Dragon*; the *Harp*; the *Swan*; *Cassiopeia*; *Persius*; *Andromeda*; the *Triangle*; *Auriga*; *Pegasus*, or the *Flying Horse*; *Equuleus*; the *Dolphin*; the *Arrow*; the *Eagle*; *Serpentarius*; and the *Serpent*,

The constellations noted by the ancients on the South side of the *Zodiac*, were fifteen, viz. Southern constellations. the *Whale*; the river *Eridanus*; the *Hare*; *Orion*; the *Great Dog*; *Little Dog*; the *Ship Argo*; *Hydra*; the *Centaur*; the *Cup*; the *Crow*; the *Wolf*; the *Altar*; the *Southern Crown*; and the *Southern Fish*. To these have been lately added the following, viz. The *Phœnix*; the *Crane*; the *Peacock*; the *Indian*; the *Bird of Paradise*; the *Southern Triangle*; the *Fly*; *Camoleon*; the *Flying Fish*; *Toucan*, or the *American Goose*; the *Water Ser-*

pent, and the *Sword Fish*. The ancients placed those particular constellations or figures in the Heavens, either to commemorate the deeds of some great man, or some notable exploit or action; or else took them from the fables of their religion, &c. And the modern astronomers do still retain them, to avoid the confusion that would arise by making new ones, when they compare the modern observations with the old ones.

Some of the principal Stars have particular names given them, as *Syrius*, *Arcturus*, &c. There are also several Stars that are not reduced into constellations, and these are called *Unformed Stars*.

Besides the Stars visible to the naked eye, there is a very remarkable space in the Heavens, called the *Galaxy*, or *Milky Way*. This is a broad circle of a whitish hue, like milk, going quite round the whole Heavens, and consisting of an infinite number of small Stars, visible thro' a telescope, tho' not discernable by the naked eye, by reason of their exceeding faintness; yet with their light they combine to illustrate that part of
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The Galaxy, or Milky Way.

the Heavens where they are, and to cause that shining whiteness.

The places of the fixed Stars, or their relative situations one from another, have been carefully observed by astronomers, and digested into catalogues. The first among the *Greeks*, who reduced the Stars into a catalogue, was *Hyparchus*, who, from his own observations, and of those who lived before him, inserted 1022 Stars into his catalogue, about 120 years before the Christian *Æra*: This catalogue has been since enlarged and improved by several learned men, to the number of 3000, of which there are a great many telescopical, and not to be discerned by the naked eye; and these are all ranked in the catalogue as the Stars of the seventh magnitude.

It may seem strange to some, that there are no more than this number of Stars visible to the naked eye; for sometimes in a clear night they seem to be innumerable: but this is only a deception of our sight, arising from their vehement sparkling, while we look upon them confusedly, without reducing them into any order; for there can seldom be seen above 1000 Stars in the whole

Heavens with the naked eye at the same time; and if we should distinctly view them, we shall not find many but what are inserted upon a good *Celestial* Globe.

Altho' the number of Stars that can be discerned by the naked eye are so few, yet it is probable there are many more which are beyond the reach of our optics, for through telescopes they appear in vast multitudes, every where dispersed throughout the whole Heaven; and the better our glasses are, the more of them we still discover. The ingenious Dr. *Hook* has observed 78 Stars in the *Pleiades*, of which the naked eye is never able to discern above 7; and in *Orion*, which has but 80 Stars in the *British* catalogue (and some of them telescopical) there has been numbered 2000 Stars.

An idea
of the U-
niverse.

Those who think that all these glorious bodies were created for no other purpose than to give us a little dim light, must entertain a very slender idea of the Divine Wisdom; for we receive more light from the *Moon* itself, than from all the *Stars* put together. And since the *Planets* are subject to the same laws of motion with our *Earth*, and some

of them not only equal, but vastly exceed it in magnitude, it is not unreasonable to suppose, that they are all habitable Worlds. And since the *Fixed Stars* are no ways behind our *Sun*, either in bigness or lustre, is it not probable that each of them have a system of *Planetary Worlds* turning round them, as we do round the *Sun*? And if we ascend as far as the smallest Star we can see, shall we not then discover innumerable more of these glorious bodies, which now are altogether invisible to us? And so *ad infinitum*, through the boundless space of the universe. What a magnificent idea must this raise in us of the *Divine Being*! Who is every where, and at all times present, displaying his Divine Power, Wisdom and Goodness, amongst all his Creatures!

The DESCRIPTION and USE
of the CELESTIAL and
TERRESTRIAL GLOBES.

*Globe or
Sphere.*

A *Globe* or *Sphere* is a round solid body, having every part of its surface equally distant from a point within it, called its *Center*; and it may be conceived to be formed by the revolution of a semicircle round its diameter.

*Great
Circle.
Hemi-
spheres.*

Any circle passing through the center of the sphere, thereby dividing it into two equal parts or segments, is called a *Great Circle*; and the segments of the sphere so divided, are called *Hemispheres*.

Every great circle has its *Poles* and *Axis*.

Poles.

The *Poles* of a great circle are two points on the surface of the sphere, diametrically opposite to one another,
and

and every where equally distant from the said circle.

The *Axis* of a circle is a right line *Axis.* passing through the center of the sphere, and through the Poles of the said circle, and is therefore perpendicular to the Plane: Hence,

All circles passing through the Poles of any great circle, intersect it in two places diametrically opposite, and also at right angles; and with respect to the said great circle, they may be called its *Secondaries.*

Secondaries.

All circles dividing the sphere into two unequal parts, are called *lesser* or *parallel Circles*, and are usually denominated by that great circle to which they are parallel. *Parallel or lesser Circles.*

The Earth being globular, its outward parts, as the several *Countries, Seas, &c.* are best, and most naturally represented upon the surface of a Globe; and when such a body has the outward parts of the Earth and Sea delineated upon its surface, and placed in their natural order and situation, it is called a *Terrestrial Globe.* *Terrestrial Globe.*

The

The Celestial Bodies appear to us as if they were all placed in the same concave sphere, therefore astronomers place the Stars according to their respective situations and magnitudes, and also the images of the constellations, upon the external surface of a Globe; for it answers the same purposes as if they were placed within a concave sphere, if we suppose the Globe to be transparent, and the eye placed in the center. A Globe having the Stars placed upon its surface, as above described, is called a *Celestial Globe*. These Globes are both placed in frames, with other appurtenances, as shall be described in a proper place.

*Celestial
Globe.*

The principal
use
of the
Globes.

The principal uses of the Globes (besides their serving as *Maps*, to distinguish the outward parts of the Earth, and the situations of the fixed Stars) is to explain and resolve the phænomena arising from the diurnal motion of the Earth round its Axis.

It has been shewed in the Introduction, that the distance of the Earth from the Sun, is no more than a point, when compared with the immense distance of the fixed Stars; therefore let
the

the Earth be in what point soever of her orbit, there will be the same prospect of the Heavens, as a spectator would observe did he reside in the Sun: And if several circles be imagined to pass thro' the center of the Earth, and others, parallel to them, be conceived to pass thro' the center of the Sun, these circles in the Heavens will seem to coincide, and to pass exactly thro' the same Stars. Wherefore as to the appearances of the fixed Stars, it is indifferent whether the Earth or the Sun be made the center of the Universe. But because it is from the Earth that we always observe the celestial bodies, and their apparent motions seem to us to be really made in the Heavens, it is more natural in explaining the phænomena arising from these motions, to place the Earth in the center. And again, because the semidiameter of the Earth, when compared to its distance from the Sun, is of no sensible magnitude, any point, upon the Earth's surface, let it be in what part soever of the orbit, may be considered as being the center of the Universe. Upon these principles, the different phænomena arising from the diurnal motion of the Earth, and the dif-

There will be the same prospect of the fixed Stars whether the spectator be placed on the Earth, or in the Sun.

different situation of a spectator upon its surface, are very naturally illustrated and explained by the Globes.

As to the alterations of seasons, &c. arising from the annual motion of the Earth round the Sun, it is indifferent which we suppose to move, the Earth or the Sun, for in both cases the effect will be the same. Wherefore because it is the Sun that appears to us to move, we say the Sun is in such a part of the ecliptic, without attributing any motion to the Earth, any more than if she had actually been at rest. For the same reason we say the Sun rises, or the Sun sets; by which we mean, that he begins to appear or disappear, without considering in the least how these effects are produced. These things are here mentioned, to obviate the objections that might be made by beginners, after they have been told that the Sun stands still.

SECT.

S E C T. I.

An Explanation of the Circles of the Sphere, and of some Astronomical Terms arising therefrom.

I N order to determine the relative situations of places upon the Earth, as well as the positions of the fixed Stars, and other Celestial phænomena, the Globe of the Earth is supposed to be environed by several imaginary circles, and these are called the *Circles of the Sphere*. These imaginary circles are either fixed, and always obtain the same position in the Heavens, or moveable, according to the position of the observer.

The Circles of the Sphere.

Those circles that are fixed, owe their origin to the two-fold motion of the Earth, and are the *Equator*, and the *Ecliptic*, with their *Secondaries* and *Parallels*.

ralls. These fixed circles are usually delineated upon the surface of the Globes.

The moveable circles are only the *Horizon*, its *Secondaries* and *Parallels*: These are represented by the wooden frame, and the brass ring, wherein the Globe is hung, and a thin plate of brass to be screwed in a proper place, upon the said ring, as occasion requires.

I. *Of the Equinoctial.*

The Equator, or Equinoctial.

I. The *Equator*, or the *Equinoctial*, is that great circle in the Heavens, in whose plane the Earth performs her diurnal motion round her axis; or it is that great circle, parallel to which the whole Heavens seem to turn round the Earth from East to West in 24 Hours.

Note, The Equator and the Equinoctial are generally synonymous terms; but sometimes the Equator particularly signifies that great circle upon the surface of the Earth, which coincides with the Equinoctial in the Heavens. This circle is also by Mariners commonly called the *Line*.

This

The equinoctial divides the globe of the Earth, and also the whole Heavens into two equal parts, North and South, which are called the *Northern* and *Southern Hemispheres*. The axis of this circle, is called the *Axis of the World*, or the *Earth's Axis*, because the Earth revolves about it (from West to East) in 24 hours. The extremes of this axis are called the *Poles of the World*, whereof that which lies in the Northern Hemisphere, is called the *North Pole*, and the other is called the *South Pole*. The equinoctial circle is always delineated upon the surface of each globe, with its name at length expressed; the axis of this circle, or the earth's axis, is only an imaginary line in the Heavens, but on the globes it is expressed by the wires about which they really turn. The Poles of the world are the two points upon the surface of the globe through which these wires pass; the North Pole is that which hath the little brass circle, with a moveable index placed round it; and the other opposite to it is the South Pole. The Northern Hemisphere is that wherein the North Pole is placed, and the opposite one is the Southern Hemisphere.

The astronomers divide all circles into 360 equal parts, called *Degrees*, each degree into 60 equal parts, called *Minutes*, each minute into 60 *Seconds*, &c. But besides this division into degrees, the equinoctial is also divided into 24 equal parts, or *Hours*, each hour into 60 *Minutes*, each minute into 60 *Seconds*, &c. so that one hour is equal to 15 degrees, each minute of time is equal to 15 minutes of a degree, &c.

2. All circles conceived to pass through the Poles of the world, intersecting the equinoctial at right angles, are, with respect to any point in the Heavens, called *Hour Circles*; and the *Circles of Ascension*, because the ascension of the Heavenly bodies, from a certain point, are by them determined.

Hour Circles or Circles of Ascension, also called Meridians.

These circles are also, with regard to places upon the Earth, called *Meridians*.

The *Meridians* are commonly drawn upon the Terrestrial Globe thro' every 15 degrees of the equinoctial, thereby making an Hour difference betwixt the places through which they pass. On the Celestial Globe there are commonly drawn but two of these *Meridians*, crossing the

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the

the equinoctial in four points equidistant from one another, thereby dividing it into four quadrants; but the intermediate ones are here supplied, and also upon the Terrestrial Globe, by the brass circle on which the Globe is hung, which is therefore called the *Brass Meridian*, The Brass Meridian. and sometimes only the *Meridian*, it serving for this purpose to all the points upon either Globe.

There is also a little brass circle fixed upon this meridian, divided into 24 Hours, having an index moveable round the axis of the globe, to be turned to any particular Hour. The use of this circle is to shew the difference of time betwixt any two meridians, and is therefore called the *Hour Circle*.

The Hour Circle.

3. All circles parallel to the equinoctial are, with respect to any point in the Heavens, called *Parallels of Declination*. So that, Parallels of Declination.

4. The *Declination of any Point* in the Heavens (as of the *Sun*, a *fixed Star*, or the like) is an arch of the meridian passing through that point, and intercepted betwixt it and the equator; and if the said point be

to the { Northward } of the equator, it is
 { Southward }
Declina- called { North } *Declination.*
tion North { South }
and South.

5. Of the parallels of declination, four are eminently distinguished by particular names, *viz.* The two *Tropics*, and the two *Polar Circles*.

The tropics are on different sides of the equator, each 23 degrees and 28 minutes distant from it; that which lies in the Northern Hemisphere, is called the *Tropic of Cancer*; and the Southern one, the *Tropic of Capricorn*.

*Tropic of
Cancer;
of Capri-
corn.*

These circles are the limits of the Sun's greatest declination, and are called tropics, because whenever the Sun arrives to them, he seems to return back again towards the equator.

6. The *Polar Circles* are each of them at the same distance from the Poles of the world, that the tropics are from the equator, *viz.* 23° 28'. That which lies near the North Pole, is called the *Arctic Circle*, from *Arctos*, a constellation situated in the Heavens near that Place; whence also this Pole is

*Arctic
Circle.*

is sometimes called the *Arctic Pole*. The *Arctic Pole*.
 other Polar circle, which is situated near
 the South Pole, is called the *Antarctic* *Antarctic*
Circle, because its position is contrary *Circle*.
 to the other; and the South Pole is *Antarctic*
 sometimes called the *Antarctic Pole*. *Pole*.

The tropics and the Polar circles have each their names expressed upon the Globes.

II. *Of the Ecliptic.*

7. The *Ecliptic* is that great circle *Ecliptic*.
 in whose plane the Earth performs its
 annual motion round the Sun; or, in
 which the Sun seems to move round the
 Earth, once in a year. This circle
 makes an angle with the equinoctial
 of 23 degrees 28 minutes, and intersects
 it in two opposite points, which are call-
 ed the *Equinoctial Points*; and the two *Equinoc-*
 points in the ecliptic that are at the *tial*.
 greatest distance from the equinoctial
 points, are called the *Solstitial Points*. *Solstitial*
 The two meridians passing through *Points*.
 those points, are, by way of eminence,
 called *Colures*; whereof that which pas- *Colures*.
 seth thro' the equinoctial points, is call-
 ed the *Equinoctial Colure*; and that *Equinocti-*
 which is at right angles to it, passing *al Colure*.

Solstitial Colure.

through the Solstitial Points, is called the *Solstitial Colure*.

The Ecliptic divided into signs.

The ecliptic is divided into 12 equal parts, called *Signs*, each sign being 30 degrees, beginning from one of the equinoctial points, and numbered from West to East; the names and characters of the twelve signs are as follows, viz.

Aries, Taurus, Gemini, Cancer, Leo, Virgo,
 1. ♈ 2. ♉ 3. ♊ 4. ♋ 5. ♌ 6. ♍
Libra, Scorpio, Sagittarius, Capricornus, Aquarius, Pisces,
 7. ♎ 8. ♏ 9. ♐ 10. ♑ 11. ♒ 12. ♓

Northern Signs.

The first six of these are called the *Northern Signs*, and possess that half of the ecliptic which is to the Northward of the equator; beginning with the first point of ♈, and ending with the last point of ♍.

Southern Signs.

The latter six are called the *Southern Signs*, because they possess the Southern half of the ecliptic; beginning at the first point of ♎, and ending with the last point of ♓.

The division of the ecliptic into signs, and the names of the colures, are particularly expressed upon the globes.

The

The signs of the ecliptic took their names from 12 constellations mentioned in the Introduction, to be situated in the Heavens near those places. It is to be observed, that the signs are not to be confounded with the constellations of the same name: For the *Sign of Aries*, is not the same with the *Constellation Aries*; the latter is a system of Stars digested into the figure of a *Ram*; but the sign of *Aries* is only 30 degrees of the ecliptic, counted from the equinoctial point ϖ , (which is reckoned the first point in the ecliptic) to the beginning of *Taurus*: Or, it is sometimes taken for all that space upon the Celestial Globe contained between the two circles passing through the first points of ϖ and γ . What has been here said of *Aries*, is to be noted of all the rest of the signs.

The constellations above-mentioned were formerly situated within the signs which now bear their names; but by a slow motion of the equinoctial points, being one degree in 72 years, the constellation *Aries* has now got into the sign γ , and so of the rest. So that *Pisces* is now got into the sign of ϖ : this slow motion in the Heavens is called the *Precession of the Equinoctial Points*.

*Poles of
the Eclip-
tic.*

The *Poles of the Ecliptic* are both situated in the Solstitial Colure, at 23 degrees, 28 minutes distance from the Pole of the world; and they take their denomination from the Hemisphere wherein they are placed, *viz.* that which lies in the { Northern } Hemisphere, is called the { North } Pole of the ecliptic. The arctic and antarctic circles, are described by the Poles of the ecliptic in the diurnal motion of the Earth round its axis, whence it seems these two circles are called *Polar*.

*Circles of
Longitude.*

*Longitude
of any
Point in
the Hea-
vens.*

*Place of a
Star.*

8. All great circles passing through the Poles of the ecliptic, and consequently intersecting it at right angles, are called *Circles of Longitude*: So that

9. The *Longitude* of any *Point* in the Heavens (as a *Star* or *Planet*, &c.) is an arch of the ecliptic contained between the circle of longitude passing thro' that point, and the equinoctial point γ . And that degree of any sign which lies under the circle of longitude, passing thro' any *Star* or *Planet*, is called the *Place* of that *Star* or *Planet*.

Note,

Note, The *Sun* never goes out of the ecliptic, and it is not usual to say the Sun's longitude, but we commonly express it the *Sun's Place*, which is that sign, degree, minute, &c. of the ecliptic, which he at any time passes.

10. All circles conceived to be drawn parallel to the ecliptic, are called *Parallels of Latitude*: So that,

11. The *Latitude* of any point in the Heavens, (as a fixed Star, &c.) is an arch of the circle of longitude, passing thro' that point, and intercepted betwixt it and the ecliptic; or, the latitude is the distance from the ecliptic; and if the said point be to the Northward of the ecliptic, it is called North Latitude; but if it be to the Southward, is called South Latitude.

*Latitude
of a Star,
&c.*

Upon the *Terrestrial Globe*, none of the circles of longitude are described; and upon the *Celestial*, they are commonly drawn thro' the beginning of every *Sign*; but they are all supplied upon both Globes, by fastening a thin plate of brass over one of the Poles of the ecliptic, and so as to be moved to any degree thereof at pleasure. The
pa-

parallels of latitude are also supplied by the graduations upon the said plate, as shall be shewn in a proper place.

We have now done with all those circles that are fixed, and such as are drawn upon the Globes themselves; we next proceed to the moveable circles.

III. *Of the Horizon.*

Horizon. 12. The *Horizon* is that great circle which divides the upper, or visible Hemisphere of the world, from the lower, or invisible: This circle is distinguished into two sorts, the *Sensible*, and the *Rational*.

Sensible Horizon. The *Sensible*, or *Apparent Horizon*, is that circle which limits or determinates our prospect, whether we are at land or sea, reaching as far as we can see, or it is that circle where the Sky and the Earth, or Water, seem to meet. When we are on *Terra Firma*, this circle commonly seems rugged and irregular; occasioned by the unevenness of the ground terminating our prospect; but at sea there are no such irregularities; the semidiameter of this circle varieth according to the height of the eye of the ob-

observer; if a man of six feet high stood upon a large plain, or the surface of the sea, he could not see above three miles round.

This circle determines the rising and setting of the Heavenly bodies, and distinguishes Day and Night.

The *Rational*, or true *Horizon*, is a *Rational Horizon* great circle passing thro' the center of the Earth, parallel to the sensible Horizon, being distant from it by the Earth's semidiameter, which is about 3980 miles: This distance is nothing in comparison of the immense distance of the Sun and the fixed Stars, therefore astronomers make no distinction between these two circles, but consider the apparent Horizon, or that wherein the Sun appears to rise and set, as passing thro' the center of the Earth.

This circle is divided by astronomers into four quadrants, and each of the quadrants into 90 degrees, &c. The four points quartering this circle are called the *Cardinal Points*, and are termed the *East, West, North, and South*. *Cardinal Points of the Horizon*. The *East* is that point of the Horizon where the Sun rises when he is in the equi-

equinoctial, or on that day when he ascends above the Horizon exactly at six o'clock; and the *West* is that point of the Horizon which is directly opposite to the East, or where the Sun sets when he is in the Equinoctial. The *South* is 90 degrees distant from the East and West, and is toward that part of the Heavens where the Sun always appears to us in *Great-Britain* at Noon; and the *North* is that part of the Heavens which is directly opposite to the South: Or, the North and South points of the Heavens may be found by turning yourself either directly towards the East or the West: If you look towards the

{ East } the { South }
 { West } the { North } will be to the right
 Hand, and the { North }
 { South } to the left.

*Points of
 the Com-
 pass.*

Besides the aforementioned divisions of the Horizon into degrees, *Mariners* divide it into 32 equal parts, which they call the *Points of the Compass*; to each of which points they give a particular name, compounded of the four Cardinals, according to what quarter of the Compass is intended.

The center of the Horizon is the
 place

place of observation, and the Poles of it are one exactly over our heads, called the *Zenith*; and the other exactly under our feet, called the *Nadir*.

*Zenith.**Nadir.*

13. All circles conceived to pass thro' the Zenith and Nadir, are called *Vertical Circles*, or *Azimuths*. Of these circles, that which passeth thro' the North and South points of the Horizon, is called the *Meridian*; so that when any object is upon the Meridian, it then bears either due South, or due North from us; and the *Azimuth* of any object is an arch of the Horizon intercepted between the vertical circle passing through it, and either the North or South part of the Meridian; which part is commonly specified.

*Vertical Circles.**Meridian.**Azimuth.*

The meridian passes thro' the Poles of the world, as well as through the Zenith and Nadir, and therefore is a secondary both of the equinoctial and the horizon: This circle divides the globe into the *Eastern* and *Western Hemispheres*, and the Poles of it are the *East* and *West* points of the *Horizon*. All the heavenly objects are, during one half of their continuance above the horizon, in the Eastern Hemisphere, and for

for the other half in the Western; so that whenever the Sun arrives upon the upper part of the meridian, it is then *Noon*, or *Mid-day*, which is the reason why this circle is called the meridian; and when he comes to the lower part, it is then *Mid-night*.

*Prime
Vertical.*

The vertical circle passing thro' the East and West points of the horizon, is called the *Prime Vertical*, or *Circle of East and West*; so that when any object is upon this circle in the Eastern hemisphere, it appears due East; and if it be in the Western hemisphere, it appears due West.

*Ampli-
tude.*

That degree in the horizon wherein any object rises or sets from the East or West points, is called the *Amplitude*; which for rising is called *Amplitude Or- tive*, and *Occasive* for setting; which must be also denominated whether it be Northerly or Southerly.

It may be observed, that the *Ampli- tude* and *Azimuth* are much the same; the amplitude shewing the bearing of any object when it rises or sets, from the East or West points of the horizon; and the azimuth, the bearing of any

any object when it is above the horizon, either from the North or South point thereof. As for example, if an object rises or sets within 10 degrees of the East or West, suppose towards the South, we accordingly say, its *Amplitude* is 10 degrees Southerly; but if an object, that is of any height above the horizon, should be in the vertical circle, passing thro' the before-mentioned point, we then say, its *Azimuth* is 80 degrees from the South, or 100 degrees from the North, both which expressions signify the same.

14. All circles drawn parallel to the horizon, in the upper hemisphere, are called *Almacantbers*, or *Parallels of Altitude*: So that the *Altitude* of any point in the Heavens is an arch of the vertical circle passing thro' that point, and intercepted betwixt it and the horizon; and if the object be upon the meridian, it is commonly called the *Meridian Altitude*. The complement of the altitude, or what it wants of 90 degrees, is called the *Zenith Distance*.

Almacantbers.
Altitudes.

Meridian Altitude.

Zenith Distance.

The horizon (by which we mean the rational) is represented by the upper surface of the Wooden frame, wherein
the

the globes are placed ; upon this horizon are described several concentric circles, the innermost of which is divided into degrees, which ought to be numbered both ways from the East and the West, until they end at 90 degrees in the North and South points. The use of these divisions is to shew the amplitudes of the Sun and Stars, at their rising and setting : Also in some convenient place upon this horizon, there is commonly noted the points of the Compass. Without the before-mentioned circle there is drawn the ecliptic with its divisions, into signs, and degrees, and a circle of months and days : The use of these two circles is to serve as a kalendar to shew the Sun's place at any time of the year, and by that means to find his place in the *Ecliptic*, drawn upon the globe itself.

The *Vertical Circles*, and the *Parallels of Altitude*, are supplied by a thin plate of brass, having a nut and screw at one end to fasten it to the brass meridian in the Zenith point ; which being done, the lower end of it may be put between the globe itself, and the inner edge of the horizon, and so turned round about to any point required.

The

The fiducial edge thereof representing the *Vertical Circles*, and the *Degrees* upon it, describing the *Parallels of Altitude*. This thin plate is called the *Quadrant of Altitude*.

*Quadrant
of Altitude.*

The center of the horizon being the place of observation, it is evident that this circle, and all the others belonging to it, are continually changed, which way soever we move; wherefore we may suppose the horizon, with its secondaries and parallels, to invest the globe like a *rete*, or net; and to be moveable every way round it. This is very naturally illustrated by the globes; if we move directly North, or directly South, the change made in the horizon is represented by moving the brass meridian (keeping the globe from turning about its axis) in the notches made in the wooden horizon, just so much as we travelled. If our course should be due East, or due West, the alterations made thereby are represented by turning the globe accordingly about its axis, the brass meridian being kept fixed; and if we steer betwixt the meridian and the East or West points, then we are to turn the brass meridian, and also the globe about its axis accordingly; the

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sum of which is, let the spectator be at what point soever of the Earth's surface, he'll there gravitate, or tend exactly toward its center, and imagine himself to be on the highest part thereof, (the unevenness of the ground not being here considered) wherefore if we turn the globe in such a manner as to bring the several progressive steps of a traveller successively to the Zenith, we shall then have the successive alterations made in the horizon, in every part of his journey. This explication being well considered, will be of help to young beginners, to conceive how the Earth is every where habitable; and how passengers can travel quite round it; for since every thing tends toward the center of the Earth, we are to conceive that point as being the lowest, and not to carry our idea of downwards any farther. Those that are diametrically opposite to us being as much upon the upper part of the Earth as we are, there being no such thing in nature as one place being higher than another, but as it is at a greater distance from the center of the Earth, let it be in what country soever.

We have now done with all the circles of the sphere, and it may be observed,

served, that the *Equinoctial*, the *Ecliptic*, and the *Horizon*, with their secondaries and parallels, are all alike; and altering their position, may be made to serve for one another. Thus, if the *Poles of the World* be brought into the *Zenith* and *Nadir*, the *Equinoctial* will coincide with the *Horizon*, the *Meridians* will be the same with the *Vertical Circles*, and the parallels of *Declination* will be the parallels of *Altitude*. After the same manner, if shifting the position, we bring the *Ecliptic* to coincide with the *Horizon*, the circles of *Longitude* will be the *Vertical Circles*, and the parallels of *Latitude* and *Altitude* will coincide.

The horizon and the equator may be either parallel, perpendicular, or oblique to each other.

15. A *Parallel Sphere* is that position where the equator coincides with the horizon, and consequently the poles of the world are in the *Zenith* and *Nadir*: The inhabitants of this sphere (if there be any) are those who live under the poles of the world. *Parallel Sphere.*

16. A *Right or Direct Sphere* is that position where the equator is perpendicular *Right Sphere.*

dicular to the horizon, the inhabitants whereof are those who live under the equinoctial.

*Oblique
Sphere.*

17. An *Oblique Sphere* is when the equinoctial and the horizon make oblique angles with each other, which every where happens but under the equator and the poles.

*Diurnal
and Nocturnal
Arch.*

The arch of any parallel of declination, which stands above the horizon, is called the *Diurnal Arch*, and the remaining part of it, which is below the horizon, is called the *Nocturnal Arch*.

That point of the equinoctial which comes to the $\left\{ \begin{array}{l} \text{Eastern} \\ \text{Western} \end{array} \right\}$ part of the horizon with any point of the Heavens, is called the $\left\{ \begin{array}{l} \text{Ascension} \\ \text{Descension} \end{array} \right\}$ of that point, counted from the beginning of ϖ ; and if it be in a right sphere, the ascension or descension is called right; but if it be an oblique sphere, it is called an oblique ascension or descension. So that

*Right
Ascension.*

18. The *Right Ascension* of the *Sun*, *Moon*, or any *Star*, &c. is an arch of the equator contained betwixt the beginning

ning of φ , and that point of the equinoctial which rises with them in a *Right Sphere*, or which comes to the meridian with them in an oblique Sphere.

19. *Oblique Ascension, or Descension*, Oblique Ascension. is an arch of the equinoctial intercepted between the beginning of φ , and that *Point* of the *Equator* which rises or sets with any point in the Heavens in an oblique Sphere.

20. *Ascensional Difference*, is the difference betwixt the right and oblique ascension or descension, and shews how long the Sun rises or sets before or after the hour of six. Ascensional Difference.

IV. *Of the Division of Time.*

The parts that time is distinguished into, are *Days, Hours, Weeks, Months,* and *Years.*

A Day is either natural or artificial.

A *Natural Day* is the space of time Natural and Artificial Day. elapsed while the Sun goes from any meridian or horary circle, till he arrives to the same again; or, it is the time contained from noon, or any particular

F 3 hour,

hour, to the next noon, or the same hour again. An *Artificial Day* is the time betwixt the Sun's rising and setting; to which is opposed the *Night*, that is, the time the Sun is hid under the horizon.

Hours, &c. The *Natural Day* is divided into 24 *Hours*, each hour into 60 *Minutes*, each minute into 60 *Seconds*, &c. The *Artificial Days* are always unequal to all the inhabitants that are not under the equator, except when the Sun is in the equinoctial points ♈ and ♎, which happens (according to our way of reckoning) about the 21st of *March*, and the 22^d of *September*; at those times the Sun rises at six and sets at six to all the inhabitants of the Earth. These days are called the *Equinoxes*, or *Equinoctial Days*; the first of which, or when the Sun is in the first point of *Aries*, is called the *Vernal Equinox*, and the latter is called the *Autumnal Equinox*: In all places where the Sun descends below the horizon, excepting under the equator, the days continually lengthen or shorten, and that faster or slower, according as the Sun is nearer to, or further from the equinoctial, until he arrives to either of the *Solstitial Points* ♄ or ♅. At those times

Equinoxes.

*Vernal
and Autumnal
Equinox.*

times the Sun seems to stand still for a few days, and then begins to return with a slow motion towards the equinoctial, still hastening his pace as he comes nearer to it: The Sun enters the tropics of ♋ and ♏, about the 21st of *June*, and the 21st of *December*, which days are sometimes called the *Solstices*; the first of which we call the *Summer Solstice*, and the latter the *Winter Solstice*.

Solstices.
Summer
and *Win-*
ter Solsti-
ces.

All nations do not begin their day, and reckon their hours alike. In *Great-Britain, France, and Spain*, and in most places in *Europe*, the day is reckoned to begin at midnight, from whence is counted twelve hours till noon, then twelve hours more till next midnight, which makes a compleat day; yet the *Astronomers* (in these countries) commonly begin their day at noon, and so reckon 24 hours till next noon, and not twice twelve, according to the vulgar computation.

The dif-
ferent be-
ginning of
the day.

The *Babylonians* began their day at Sun-rising, and reckoned 24 hours till he rose again. This way of computation we call the *Babylonish Hours*. In several parts of *Germany* they count their hours from Sun-setting, calling the first

Babyl-
onish Hours.

Italian Hours.

hour after the Sun has set, the first hour, &c. till he sets the next day, which they call the 24th hour: These are commonly called the *Italian Hours*. According to both these ways of computation, their hours are commonly either a little greater or less than the $\frac{1}{24}$ part of a natural day, in proportion as the Sun rises or sets sooner or later in the succeeding days. They have also this inconvenience, that their mid-day and mid-night happen on different hours, according to the seasons of the year.

Jewish Hours.

The *Jews* and the *Romans* formerly divided the artificial days and nights each into 12 equal parts; these are termed the *Jewish Hours*, and are of different lengths, according to the seasons of the year; a *Jewish Hour* in summer being longer than one in winter, and a night-hour shorter. This method of computation is now in use among the *Turks*, and the hours are stiled the *first hour*, *second hour*, &c. of the day or night; so that *Mid-day* always falls on the sixth hour of the day. These hours are also called *Planetary Hours*, because in every hour one of the seven Planets were supposed to preside over the World, and so take it by turns. The first hour after Sun-

Planetary Hours.

Sun-rising on *Sunday* was allotted to the *Sun*; the next to *Venus*; the third to *Mercury*; and the rest in order to the *Moon*, *Saturn*, *Jupiter*, and *Mars*. By this means on the first hour of the next day, the Moon presided, and so gave the name to that day; and so seven days by this method, had names given them from the Planets that were supposed to govern on the first hour,

A *Week* is a system of seven days, in *A Week.* which each day is distinguished by a different name. In most countries these days are called after the names of the seven Planets, as above noted. All nations that have any notion of religion, lay apart one day in seven for public worship; the day solemnized by *Christians* is *Sunday*, or the first day of the week, being that on which our Saviour rose from the grave, on which the apostles afterwards used more particularly to assemble together to perform divine worship. The *Jews* observed *Saturday*, or the seventh day of the week, for their sabbath, or day of rest, being that appointed in the fourth commandment under the Law. The *Turks* perform their religious ceremonies on *Friday*.

A Month. A *Month* is properly a certain space of time measured by the Moon in her course round the Earth. A *Lunar Month* is either *Periodical* or *Synodical*. A *Periodical and Synodical Month.* *Periodical Month* is that space of time the Moon takes to perform her course from one point in the ecliptic till she arrives to the same again, which is 27 days, and some odd hours; and a *Synodical Month* is the time betwixt one new Moon and the next new Moon, which is commonly about 29½ days. But a *Civil Month* is different from these, and consists of a certain number of days, fewer or more, according to the laws and customs of the country where they are observed.

The compleatest period of time is a *Year*, in which all the variety of seasons return, and afterwards begin a-new. A *Year* is either *Astronomical* or *Civil*. An *Astronomical Year* is either a *Sydereal*, wherein the Sun departing from a fixed Star, returns to it again; or *Tropical*, which is the space of time the Sun takes to perform his course from any point of the ecliptic, till he returns to it again.

A *Tropical Year* consists of 365 days, 5 hours, and 49 minutes; this is the time in which all the seasons completely return, which is a small matter less than a Sydereal Year.

The *Civil Year* is the same with the *Political*, established by the laws of a country; and is either moveable or immoveable. The moveable year consists of 365 days, being less than the tropical year by almost six hours, and is called the *Egyptian Year*, because observed in that Country. *Egyptian Year.*

The *Romans* divided the year into 12 kalendar months, to which they gave particular names, and are still retained by most of the *European* nations, *viz.* *January, February, March, April, May, June, July, August, September, October, November, and December.* The number of days in each month may be known by the following verses:

*Thirty Days hath September,
April, June, and November;
February hath Twenty-eight alone,
And all the rest have Thirty-one.*

The

The year is also divided into four quarters or seasons, *viz.* *Spring*, *Summer*, *Autumn*, and *Winter*. These quarters are properly made when the Sun enters into the equinoctial and solstitial points of the ecliptic; but in civil uses they are differently reckoned, according to the customs of several countries. In *England*, we commonly reckon the first day of *January* to be the first in the year, which is therefore vulgarly called *New-Year's Day*; but in political and ecclesiastical affairs, the year is reckoned to commence on *Lady-day*, which is the 25th of *March*; and from thence to *Midsummer-day*, which is the 24th of *June*, is reckoned the first quarter; from *Midsummer-day* to *Michaelmas-day*, which is the 29th of *September*, is the second quarter; the third quarter is reckoned from *Michaelmas-day* to *Christmas-day*, which is the 25th of *December*; and from *Christmas-day* to *Lady-day*, is reckoned the last quarter in the year. In common affairs, a quarter is reckoned from a certain day to the same in the fourth month following. Sometimes a month is reckoned four weeks, or 28 days, and so a quarter 12 weeks. To all the inhabitants
in

in the {Northern } Hemisphere, their
 {Southern }
Midsummer is properly when the Sun
 is in the tropic of {Cancer, }
 {Capricorn, } and
 their *Mid-winter* at the opposite time
 of the year; but those who live under
 the equinoctial have two winters, &c.
 when the Sun is in either tropic; tho'
 indeed properly, there is no season that
 may be called winter in those parts of
 the world.

The *Egyptian* year of 365 days being less than the true solar year, by almost six hours, it follows, that four such years are less than four solar years by a whole day; and therefore in 365 times four years, that is, in 1460 years, the beginning of the years move through all the seasons. To remedy this inconveniency, *Julius Cæsar* (considering that the six hours, which remain at the end of every year, will in four years make a natural day) ordered that every fourth year should have an intercalary day, which therefore consists of 366 days; the day added was put in the month of *February*, by postponing *St. Matthias's* day, which in common years fall on the 24th, to 25th of the said month,

*Biffextile,
or Leap-
Year.*

month, all the fixed feasts in the year from thenceforwards falling a week-day later than otherwise they would. According to the *Roman* way of reckoning, the 24th of *February* was the sixth of the kalends of *March*, and it was ordered that for this year there should be two sixths, or that the sixth of the kalends of *March* should be twice repeated; upon which account the year was called *Biffextile*, which we now call the *Leap-Year*.

To find whether the year of our Lord be leap-year, or the first, second, or third after; divide it by four, and the remainder, if there be any, shews how many years it is after leap-year; but if there be no remainder, then that year is leap-year: Or, you may omit the hundreds and scores, and divide the residue by 4, *Examp.* 1757, omitting the hundreds and the twenties, I divide the residue 17, by 4, and the remainder 1, shews it to be the first after leap-year.

This method of reckoning the year, *viz.* making the common year to consist of 365 days, and every fourth year to have 366 days, was formerly
8 used

in *Great-Britain* and *Ireland*, and is still in use in some of the Northern parts of *Europe*, and is called the *Julian Account*, or the *Old Style*.^{*Julian Account, or the Old Style.*} But the time appointed by *Julius Cæsar* for the length of a solar year is too much; for the Sun finishes his course in the ecliptic, in 365 days, 5 hours, and 49 minutes, which is 11 minutes less than the civil year; and therefore he again begins his circuit 11 minutes before the civil year is ended; and so much being gained every year, amounts in 131 years, to a whole day. So that if the Sun in any year entered the equinox upon the 20th of *March* at noon, after the space of 131 years, he'll enter the same point on the same hour, on the 19th of *March*. And therefore the equinoxes will not always fall on the same day of the month, but by degrees will move towards the beginning of the year.

At the time of the *Council of Nice*, (when the terms were settled for observing of *Easter*) the *Vernal Equinox* fell upon the 21st of *March*; but by its falling backwards 11 minutes every year, it was found that in *Anno 1582*, when the kalendar was corrected, the Sun entered the equinoctial circle on the 11th
of

of *March*, having departed ten whole days from its former place in the year: and therefore Pope *Gregory* the XIIIth, designing to place the equinoxes in their situation with respect to the year, took these ten days out of the kalendar, and ordered that the 11th of *March* should be reckoned as the twenty-first: And to prevent the seasons of the year from going backwards for the future, he ordered every hundredth year, which in the *Julian* form was to be a *Bissextile*, should be a common year, and consist only of 365 days; but that being too much, every fourth hundred was to remain *Bissextile*. This form of reckoning being established by the authority of Pope *Gregory* XIII. is called the *Gregorian Account*, or the *New Style*; and is observed in all the countries where the authority of the Pope is acknowledged, and likewise by several nations of the reformed religion. There being now above an hundred years past, since the reformation was made in the kalendar, the *Gregorian* account has accordingly got before the *Julian* one day more than it was in the time of its institution, the difference between these two accounts being now eleven days; so that the first day of any month, according

*Gregorian
Account,
or New
Style.*

to that way of reckoning, is the 12th of the same month, according to the New Style.

I shall conclude this section with a brief account of the Atmosphere.

The *Atmosphere* is that thin body of ^{Atmo-}air which surrounds the Earth, in which ^{sphere.}the clouds hover, and by which, in their descent, they are broke into drops of rain; which sometimes, according to the warmth or coldness of air, are froze into *Snow*, or *Hailstones*. *Thunder* and *Lightning* are also made in the *Atmosphere*, and wind is nothing else but a percussion of the air, occasioned by its different density in different places. The benefits we receive from the atmosphere are innumerable; without air no earthly creature could live, as is plainly proved by experiments made by the *Air-Pump*; and the wholesomeness of a climate chiefly depends upon that of its air: If there was no atmosphere to reflect the rays of the Sun, no part of the heavens would be lucid and bright, but that wherein the Sun was placed; and if a spectator should turn his back towards the Sun, he would immediately perceive it to be quite dark, and the

least Stars would be seen shining as they do in the clearest night; and the Sun immediately before his setting, would shine as brisk as at noon, but in a moment, as soon as he got below the horizon, the whole hemisphere of the Earth would be involved in as great a darkness as if it were midnight.

But by means of the atmosphere it happens, that while the Sun is above the horizon, the whole face of the heavens is strongly illuminated by its rays, so as to obscure the faint light of the Stars, and render them invisible; and after Sun-setting, though we receive no direct light from him, yet we enjoy its reflected light for some time: For the atmosphere being higher than we are, is a longer time before it is withdrawn from the Sun (as if a man was to run to the top of a steeple, he might see the Sun after it had been set to those at the bottom.) The rays which the atmosphere receives from the Sun, after he is withdrawn from our sight, are by refraction faintly transmitted to us; until the Sun having got about 18 degrees below the horizon, he no longer enlightens our atmosphere, and then all that part thereof which is over us be-

comes dark. After the same manner in the morning, when the Sun comes within 18 degrees of our horizon, he again begins to enlighten the atmosphere, and so more and more by degrees, until he rises and makes full day.

This small illumination of the atmosphere, and the state of the Heavens between day and night, is called the *Twilight*, or the *Crepusculum*.

Twilight,
or *Crepus-*
culum.

The duration of twilight is different in different climates, and in the same place at different times of the year. The beginning or ending of twilight being accurately given, we may from thence easily find the height of the atmosphere, which is not always the same. The mean height of the atmosphere is computed to be about 40 miles; but it is probable, the air may extend itself a great deal further, there being properly no other limits to it, as we can conceive, but as it continually decreases in density the more remote it is from the Earth, in a certain ratio; which at last, as to our conception, must in a manner terminate.

S E C T. II.

Geographical Definitions.

Of the Situations of Places upon the Earth; of the different Situations of its Inhabitants; of Zones and Climates.

THE situations of places upon the Earth, are determined by their Latitude and Longitude.

Latitude. I. The *Latitude* of any place (upon the Earth) is its nearest distance, either North or South from the Equator; and if the place be in the { Northern } hemisphere, it is accordingly called { North } *Latitude*; and is measured by an arch of the meridian intercepted betwixt the zenith of the said place, and the equator. And all places that lie on the same side, and at the same distance from the equator,

tor, are said to be in the same parallel of latitude: the parallels in *Geography*, being the same with the parallels of declination in *Astronomy*.

From this definition arise the following Corollaries.

(1.) *That no place can have above 90 degrees of latitude, either North or South.*

(2.) *Those places that lie under the equinoctial (or thro' which the equator passes) have no latitude, it being from thence that the calculation of latitudes is counted; and those places that lie under the Poles have the greatest latitude, those points being at the greatest distance from the equator.*

(3.) *The latitude of any place is always equal to the elevation of the Pole in the same place above the horizon; and is therefore often expressed by the Pole's height, or elevation of the Pole; the reason of which is, because from the equator to the Pole there is always the distance of 90 degrees, and from the zenith to the horizon the same number of degrees, each of these including the distance from the zenith to the Pole: That distance therefore*

being taken away from both, will leave the distance from the zenith to the equator, (which is the latitude) equal to the distance of the Pole to the horizon.

(4.) The elevation of the equator in any place is always equal to the complement of the latitude of the same place.

(5.) A ship sailed directly $\left\{ \begin{array}{l} \text{towards} \\ \text{from} \end{array} \right\}$
 the equator $\left\{ \begin{array}{l} \text{lessens} \\ \text{augments} \end{array} \right\}$ her latitude,
 (or $\left\{ \begin{array}{l} \text{depresses} \\ \text{raises} \end{array} \right\}$ the Pole) just so much
 as is her distance sailed.

*Difference
of Lati-
tude.*

2. *Difference of latitude* is the nearest distance betwixt any two parallels of latitude, shewing how far the one is to the Northward or Southward of the other, which can never exceed 180 degrees. And when the two places are in the same hemisphere (or on the same side of the equator) the lesser latitude subtracted from the greater, and when they are on different sides of the equator, the two latitudes added together, gives the difference of latitude.

3. The

3. The *Longitude* of any place (upon the Earth) is an arch of the equator, contained betwixt the meridian of the given place, and some fixed or known meridian; or, it is equal to the angle formed by the two meridians, which properly can never exceed 180 degrees, tho' sometimes the Longitude is counted Easterly quite round the globe.

Since the meridians are all moveable, and not one that can be fixed in the heavens, (as the equinoctial circle is fixed, from whence the latitudes of all places are determined to be so much either North or South) the longitudes of places cannot so well be fixed from any other meridian, but every Geographer is at his liberty to make which he pleases his first meridian, from whence to calculate the longitudes of other places. Hence it is, that geographers of different nations reckon their longitudes from different meridians, commonly choosing the meridian passing through the metropolis of their own country for their first: Thus, the *English* geographers generally make the meridian of *London* to be their first, the *French* that of *Paris*, and the *Dutch* that of *Amsterdam*, &c. and mariners

generally reckon the longitude from the last known land they saw. This arbitrary way of reckoning the longitude from different places, makes it necessary, whenever we express the longitude of any place, that the place from whence it is counted be also expressed.

From the preceding definitions arise the following corollaries :

1. *If a body should steer directly North, or directly South, quite round the globe, he'll continually change his latitude ; and pass through the two Poles of the world, without deviating the least from the meridian of the place he departed from ; and consequently, on his return will not differ in his account of time from the people residing in the said place.*

2. *If a body should steer round the globe, either due East, or due West, he'll continually change his longitude, but will go quite round without altering his latitude ; and if his course shall be due East, he'll gain a day compleatly in his reckoning, or reckon one day more than the inhabitants of the place from whence he departed ; or if his course had been West, he would have lost one day, or reckon one less.*

The

The reason of which is evident ; for admitting our traveller steers due East, so many miles in one day as to make his difference of longitude equivalent to a quarter of an hour of time, it is evident that the next day the Sun will rise to him a quarter of an hour sooner than to the inhabitants of the place from whence he departed ; and so daily, in proportion to the rate he travels, which in going quite round, will make up one natural day. In like manner, if he steers due West after the same rate, he'll lengthen each day a quarter of an hour, and consequently the Sun will rise to him so much later every day ; by which means, in going quite round, he'll lose one day compleat in his reckoning. From whence it follows,

3. *If two bodies should set out from the same place, one steering East, and the other West, and so continue their courses quite round, until they arrive at the place from whence they set out, they'll differ two days in their reckoning at the time of their return.*

4. *If a body should steer upon an oblique course (or any where betwixt the meridian and the East or West points) he'll*
con-

The Description and Use

continually change both latitude and longitude, and that more or less, according to the course he steers; and if he should go quite round the globe, he'll differ in his account of time, as by the second Corol.

5. The people residing in the Easternmost of any two places, will reckon their time so much the sooner than those who live in the other place, according to the difference of longitude betwixt the two places, allowing one hour for every 15 degrees, &c. and the contrary.

II. *Of Zones and Climates, &c.*

Zones, Torrid, Temperate, and Frigid. 4. *Zones* are large tracts of the surface of the Earth, distinguished by the tropics and polar circles, being five in number; viz. one *Torrid*, two *Temperate*, and two *Frigid*.

The *Torrid*, or *Burning Zone*, is all the space comprehended between the two tropics: The ancients imagined this tract of the Earth to be uninhabitable, because of the excessive heat, it being so near the Sun. All the inhabitants of the torrid zone have the Sun in their zenith, or exactly over their heads twice in every year; excepting those who live
ex-

exactly under the two tropics, where the Sun comes to their zenith only once in a year.

The two *Temperate Zones* lie on either side of the globe, between the tropics and the polar circles.

The two *Frigid Zones* are those spaces upon the globe that are included between the two polar circles.

The inhabitants of the Earth are also distinguished by the diversity of their *Shadows*. Those who live in the torrid zone, are called *Amphiscians*, because their noon-shadow is cast different ways, according as the Sun is to the northward or southward of their zenith; but when the Sun is in their zenith, they are called *Ascians*.

The inhabitants of the temperate zones, are called *Heteroscians*, because their noon-shadow is always cast the same way: But those who live under the tropics are called *Ascians Heteroscians*; those who live in the frigid zones are called *Periscians*, because sometimes their shadow is cast round about them.

These

These hard names are only *Greek* words, importing how the Sun casts the shadow of the several inhabitants of the Earth; which would be a too trifling distinction to be made here, was it not for the sake of complying with custom.

The inhabitants of the Earth are also distinguished into three sorts, in respect to their relative situation to one another, and these are called the *Periæci*, *Antæci*, and *Antipodes*.

Periæci.

5. The *Periæci* are those who live under opposite points of the same parallel of latitude. They have their seasons of the year at the same time, and their days and nights always of the same length with one another, but the one's *Noon* is the other's *Midnight*; and when the Sun is in the equinoctial, he rises with the one, when he sets with the other. Those who live under the Poles have no *Periæci*.

Antæci.

6. The *Antæci* live under the same meridian, and in the same latitude, but on different sides of the equator; their seasons of the year are contrary, and the days of the one are equal to the nights

nights of the other, but the hour of the day and night is the same with both; and when the Sun is in the equinoctial, he rises and sets to both exactly at the same time. Those who live under the equator have no *Antæci*.

7. The *Antipodes* are those who live *Antipodes*. diametrically opposite to one another, standing, as it were, exactly feet to feet: Their days and nights, summer and winter, are at direct contrary times.

The surface of the Earth is by some distinguished into *Climates*.

8. A *Climate* is a tract of the surface *Climates*. of the Earth, included between two such parallels of latitude, that the length of the longest day in the one exceeds that in the other by half an hour.

The whole surface of the Earth is considered as being divided into 60 climates, *viz.* from the equator to each of the polar circles 24, arising from the difference of $\frac{1}{2}$ an hour in the length of their longest days; and from the polar circles to the Poles themselves, are six, arising from the difference of an entire month,

month, the Sun being seen in the first of these a whole month without setting; in the second two; and in the third, three months, &c. These climates continually decrease in breadth the farther they are from the equator. How they are framed, *viz.* the parallel of latitude in which they end (that being likewise the beginning of the next) with the respective breadth of each of them, is shewed in the following Table:

A TABLE of the CLIMATES.

CLIMATES between the Equator and the Polar Circles.

Cli- mates.	Longest Day.	Latitude.		Breadth.		Cli- mates	Longest Day.	Latitude.		Breadth.	
		D.	M.	D.	M.			D.	M.	D.	M.
1	12 $\frac{1}{2}$	8	34	8	34	13	18 $\frac{1}{2}$	60	0	1	33
2	13	16	44	8	10	14	19	61	19	1	19
3	13 $\frac{1}{2}$	24	12	7	28	15	19 $\frac{1}{2}$	62	26	1	7
4	14	30	48	6	36	16	20	63	23	0	57
5	14 $\frac{1}{2}$	36	31	5	43	17	20 $\frac{1}{2}$	64	10	0	47
6	15	41	24	4	53	18	21	64	50	0	40
7	15 $\frac{1}{2}$	45	32	4	8	19	21 $\frac{1}{2}$	65	22	0	32
8	16	49	2	3	30	20	22	65	48	0	26
9	16 $\frac{1}{2}$	52	0	2	58	21	22 $\frac{1}{2}$	66	7	0	19
10	17	54	30	2	30	22	23	66	21	0	14
11	17 $\frac{1}{2}$	56	38	2	8	23	23 $\frac{1}{2}$	66	29	0	8
12	18	58	27	1	49	24	24	66	32	0	3

CLIMATES between the Polar Circles and the Poles.

Length of Days.		Latitude.		Length of Days.		Latitude.	
Months.		D.	M.	Months.		D.	M.
1		67	17	4		78	2
2		69	39	5		83	20
3		74	18	6		90	0

III. Of the Poetical rising and setting of the Stars.

Cosmical, Acronical, and Heliacal rising and setting The ancient Poets make frequent mention of the Stars rising and setting, either *Cosmically*, *Acronically*, or *Heliacally*; whence these distinctions are called *Poetical*.

A Star is said to *rise* or *set Cosmically*, when it rises or sets at Sun-rising; and when it *rises* or *sets* at Sun-setting, it is said to rise or set *Acronically*. A Star *rises Heliacally*, when first it becomes visible, after it had been so near the Sun as to be hid by the splendor of his rays: And a Star is said to *set Heliacally*, when it is first immerfed, or hid by the Sun's rays.

The *Fixed Stars*, and the three superior Planets, *Mars*, *Jupiter*, and *Saturn*, rise *Heliacally* in the morning; but the Moon rises *Heliacally* in the evening, because the Sun is swifter than the superior Planets, and slower than the Moon.

IV. Of the surface of the Earth, considered as it is composed of Land and Water.

The Earth consists naturally of two parts, Land and Water, and therefore it

it is called the *Terraqueous Globe*. Each of these elements is subdivided into various forms and parts, which accordingly are distinguished by different names.

I. *Of the Land.*

The land is distinguished into *Continents, Islands, Peninsula's, Isthmus's, Promontories, Mountains, or Coasts.*

9. A *Continent* is a large quantity *Continent.* of land, in which many great countries are joined together, without being separated from each other by the sea: such are *Europe, Asia, Africa*, and the vast continent of *America*; which four are the principal divisions of the Earth. A continent is sometimes called the *Main Land*.

*Main
Land.*

10. An *Island* is a country, or por- *Island.* tion of land, environed round with water: such are *Great-Britain and Ireland; Sardinia, Sicily, &c.* in the *Mediterranean Sea*; the *Isles of Wight, Anglesey, &c.* near *England*. Also a small part of dry land, in the midst of a river, is called an island; and a greater island, when compared to a lesser, is

H called

called the continent; as if we compare the *Isle of Wight* to *England*, the latter may be properly called the continent.

Peninsula. 11. A *Peninsula* is a part of land almost environed with water, save one narrow neck adjoining it to the continent; or which is almost an island: such is *Denmark* joining to *Germany*; also *Africa* is properly a large peninsula joining to *Asia*.

Isthmus. 12. An *Isthmus* is a narrow neck of land joining a peninsula to the continent; as the *Isthmus of Sues*, which joins *Africa* to *Asia*, that of *Panama*, joining North and South *America*, &c.

Promontory. 13. A *Promontory* is a high part of land stretching out into the sea, and is often called a *Cape* or *Headland*: such is the *Cape of Good Hope* in the South of *Africa*; *Cape Finistre* on the West of *Spain*; also the *Lizard Point*, and the *Land's End*, are two Capes or Headlands on the West of *England*.
Mountain. A *Mountain* is a high part of land in the midst of a country, over-topping the adjacent parts.

14. A *Coast* or *Shore* is that part of ^{*A Coast,*} land which borders upon the sea, ^{*or Shore.*} whether it be in islands or a continent: And that part of the land which is far distant from the sea, is called the *Inland* ^{*Inland.*} *Country*. These are the usual distinctions of the land.

The Water is distinguished into *Oceans, Seas, Lakes, Gulfs, Straits,* and *Rivers.*

15. The *Ocean*, or *Main Sea*, is a ^{*The Ocean,*} vast spreading collection of water, ^{*an, or*} not ^{*Main Sea.*} divided or separated by lands running between; such is the *Atlantic* or *Western Ocean*; between *Europe* and *America*; the *Pacific Ocean*, or *South Sea*, &c.

Note, Those parts of the ocean which border upon the land, are called by various names, according to those of the adjacent countries; as, the *British Sea*, the *Irish Sea*, the *French* and *Spanish Sea*.

16. A *Lake* is a collection of deep ^{*A Lake.*} standing water, inclosed all round with land, and not having any visible and open communication with the sea: But when this lake is very large, it is commonly

monly called a sea; as the *Caspian Sea* in *Asia*, &c.

A Gulf. 17. A *Gulf* is a part of the sea almost encompassed with land, or that which runs up a great way into the land; as, the *Gulf of Venice*, &c. But if it be very large, 'tis rather called an *Inland Sea*; as the *Baltic Sea*, the *Mediterranean Sea*, the *Red Sea*, or the *Arabian Gulf*, &c. And a small part of sea thus environed with land is usually called a *Bay*. If it be but a very small Part, or, as it were, a small arm of the sea, that runs but a few miles between the land, it is called a *Creek* or *Haven*.

Creek or Haven.

A Strait. 18. A *Strait* is a narrow passage lying between two shores, whereby two seas are joined together; as, the *Straits of Dover*, between the *British Channel* and the *German Sea*; the *Straits of Gibraltar*, between the *Atlantic* and the *Mediterranean Sea*. The *Mediterranean* itself is also sometimes called the *Straits*.

These are all the necessary terms commonly used in *Geography*. The names of the several countries and seas, and all the principal divisions of the Earth, the reader will find expressed upon

upon the Terrestrial Globes. To give a tolerable account of the produce of each country, the genius of the people, their political institutions, &c. is properly a particular subject of itself, and quite foreign to our design. We shall next proceed to the use of the Globes; but first, it may not be amiss to take a short *review* of their appurtenances.

Those circles of the sphere that are *fixed*, are (as has been already said) drawn upon the *Globes* themselves; those that are *moveable*, are supplied by the *Brass Meridian*, the *Wooden Horizon*, and the *Quadrant of Altitude*.

1. That side of the *Brazen Meridian*, *Brass Meridian.* which is divided into degrees, represents the *true Meridian*; this side is commonly turned towards the East, and 'tis usual to place the globe so before you, that the North be to the right-hand, and the South to the left. The meridian is divided into 4 quadrants, each being 90 degrees, two of which are numbered from that part of the equinoctial, which is above the horizon, towards each of the Poles; the other two quadrants are numbered from the Poles towards the equator. The reason why

two quadrants of the meridian are numbered from the equator, and the other two from the Poles, is because the former of these two serve to shew the distance of any point on the globe from the equator, and the other to elevate the globe to the latitude of the place.

*Wooden
Horizon.*

2. The upper side of the wooden frame called the *Wooden Horizon*, represents the true horizon; the circles drawn upon this plane have been already described; we may observe, that the first point of γ is the East, and the opposite being the first point of α is the West, the meridian passing through the North and South points.

*Quadrant
of Altitude.*

3. The *Quadrant of Altitude* is a flexible plate of thin brass, having a nut and screw at one end, to be fastened to the meridian of either globe, as occasion requires. The edge of this quadrant which has the graduations upon it, called the fiducial edge, is that which is always meant whenever we make mention of the quadrant of altitude.

Hour Circle.

4. The *Horary or Hour Circle*, is divided into twice twelve hours, the two XII's coinciding with the meridian; the
upper-

uppermost XII. is that at *Noon*, and the lowermost towards the horizon is XII. at *Night*. The hours on the *East* side of the meridian are the *Morning Hours*, and those on the *West* side the *Hours after Noon*. The axis of the globe carries round the *Hand* or *Index* which points the hour, and passes through the center of the hour circle.

The things above described are common to both globes ; but there are some others which are peculiar or proper to one sort of globe. The two *Colures*, and the *Circles of Latitude* from the ecliptic, belong only to the *Celestial Globes* ; also the ecliptic itself does properly belong only to this globe, tho' it is always drawn on the *Terrestrial*, for the sake of those that might not have the other globe by them. The equinoctial on the celestial globe is always numbered into 360 degrees, beginning at the equinoctial point γ ; but on the terrestrial, it is arbitrary ; where these numbers commence, according to the meridian of what place you intend for your first ; and the degrees may be counted either quite round to 360, or both ways, 'till they meet in the opposite part of the meridian, at 180.

S E C T. III.

The USE of the GLOBES.

PROBLEM I. *To find the Latitude and Longitude of any given Place upon the Globe; and, on the contrary, the Latitude and Longitude being given, to find the Place.*

I. **T**URN the globe round its axis, 'till the given place lies exactly under the (Eastern side of the brass) meridian; then that degree upon the meridian, which is directly over it, is the *Latitude*; which is accordingly North or South, as it lies in the Northern or Southern hemisphere.

The globe remaining in the same position, that degree upon the equator which is cut by the brazen meridian, is the *Longitude* required from the first meridian upon the globe. If the longitude is counted both ways from the first meridian,

ridian upon the globe, then we are to consider, whether the given place lies Easterly or Westerly from the first meridian, and the longitude must be expressed accordingly.

The *Latitudes* of the following places; and, upon a globe where the longitude is reckoned both ways from the meridian of *London*, their longitudes will be found as follow :

	<i>Latitude.</i>	<i>Longitude.</i>
	Deg.	Deg.
<i>Rome</i> - - -	42 North.	$12\frac{1}{2}$ East.
<i>Paris</i> - - -	$48\frac{3}{4}$ N.	$2\frac{1}{2}$ E.
<i>Mexico</i> - -	20 N.	102 W.
<i>Cape Horn</i> -	56 S,	$67\frac{1}{2}$ W.

2. *The Latitude and Longitude being given, to find the Place.*

Seek for the given longitude in the equator, and bring that point to the meridian; then count from the equator on the meridian the degree of latitude given, towards the arctic and antarctic Pole, according as the latitude is Northerly or Southerly, and under that degree of latitude lies the *Place* required.

PROB.

PROB. II. *To find the Difference of Latitude between any two given Places.*

Bring each of the places proposed successively to the meridian, and observe where they intersect it, then the number of degrees upon the meridian, contained between the two intersections, will be the *Difference of Latitude* required. Or, if the places proposed are on the same side of the equator, having first found their latitudes, subtract the lesser from the greater; but if they are on contrary sides of the equator, add them both together, and the difference in the first case, and the sum in the latter, will be the difference of latitude required.

Thus the difference of latitude betwixt *London* and *Rome* will be found to be $9\frac{1}{4}$ degrees; betwixt *Paris* and *Cape Bona Esperance* 83 degrees.

PROB. III. *To find the Difference of Longitude betwixt any two given Places.*

Bring each of the given places successively to the meridian, and see where the meridian cuts the equator each time; the number of degrees contained betwixt those two points, if it be less than

180 degrees, otherwise the remainder to 360 degrees, will be the difference of longitude required. Or,

Having brought one of the given places to the meridian, bring the index of the hour circle to 12 o'clock; then having brought the other place to the meridian, the number of hours contained between the place the index was first set at, and the place where it now points, is the difference of longitude in time betwixt the two places.

Thus the difference of longitude betwixt *Rome* and *Constantinople* will be found to be $16\frac{1}{7}$ degrees, or 1 hour and six minutes; betwixt *Mexico* and *Pekin* in *China*, 142 degrees, or $9\frac{1}{2}$ hours.

PROB. IV. *Any Place being given, to find all those Places that are in the same Latitude with the same Place.*

The latitude of any given place being marked upon the meridian, turn the globe round its axis, and all those places that pass under the same mark are in the same latitude with the given place, and have their days and nights of equal lengths. And when any place
is

is brought to the meridian, all the inhabitants that lie under the upper semi-circle of it, have their Noon or Mid-day at the same point of absolute time exactly.

PROB. V. *The day of the Month being given, to find the Sun's Place in the Ecliptic, and his Declination.*

I. *To find the Sun's Place* : Look for the day of the month given in the kalendar of months upon the horizon, and right against it you'll find that sign and degree of the ecliptic which the Sun is in. The Sun's place being thus found, look for the same in the ecliptic line which is drawn upon the globe, and bring that point to the meridian, then that degree of the meridian, which is directly over the Sun's place, is the *Declination* required ; which is accordingly either North or South, as the Sun is in the Northern or Southern signs. Thus,

	<i>Sun's Place.</i>			<i>Declination.</i>	
	Deg.	Min.	Deg.	Min.	
<i>April 23</i>	♈	3	00	12	32 N.
<i>July 31</i>	♋	7	51	18	20 N.
<i>October 26</i>	♏	2	49	12	28 S.
<i>January 20</i>	♊	0	49	20	07 S.

PROB.

PROB. VI. *To rectify the Globe for the Latitude, Zenith, and the Sun's Place.*

1. *For the Latitude:* If the place be in the Northern hemisphere, raise the arctic Pole above the horizon; but for the South latitude you must raise the antarctic; then move the meridian up and down in the notches, until the degrees of the latitude counted upon the meridian below the Pole, cuts the horizon, and the globe is adjusted to the latitude.

2. *To rectify the Globe for the Zenith:* Having elevated the globe according to the latitude, count the degrees thereof upon the meridian from the equator, towards the elevated Pole, and that point will be the zenith or the vertex of the place; to this point of the meridian fasten the quadrant of altitude, so that the graduated edge thereof may be joined to the said point.

3. Bring the Sun's place in the ecliptic to the meridian, and then set the hour index to XII at Noon, and the globe will be rectified *to the Sun's Place*. If you have a little mariner's compass, the meridian of the globe may be easily set to the meridian of the place.

PROB. VII. *To find the Distance between any two given places upon the Globe, and to find all those places upon the globe that are at the same distance from a given place*

Lay the quadrant of altitude over both the places, and the number of degrees intercepted between them being reduced into miles, will be the distance required: Or, you may take the distance betwixt the two places with a pair of compasses, and applying that extent to the equator, you'll have the degrees of distance as before.

Note, A geographical mile is the $\frac{1}{60}$ th part of a degree; whereof if you multiply the number of degrees by 60, the product will be the number of geographical miles of distance sought; but to reduce the same into *English* miles, you must multiply by 70, because about 70 *English* miles make a degree of a great circle upon the superficies of the Earth.

Thus, the distance betwixt *London* and *Rome* will be found to be about 13 degrees, which is 780 geographical miles.

If

If you rectify the globe for the latitude and zenith of any given place, and bring the said place to the meridian; then turning the quadrant of altitude about, all those places that are cut by the same point of it, are at the same distance from the given place.

PROB. VIII. *To find the angle of position of Places, or the angle formed by the meridian of one Place, and a great circle passing through both the Places.*

Having rectified the globe for the latitude and zenith of one of the given places, bring the said place to the meridian, then turn the quadrant of altitude about, until the fiducial edge thereof cuts the other place, and the number of degrees upon the horizon, contained between the said edge and the meridian, will be the angle of position sought.

Thus, the angle of position at the *Lizard*, between the meridian of the *Lizard* and the great circle, passing from thence to *Barbadoes* is 69 degrees South-Westerly; but the angle of position between the same places at *Barbadoes*, is but 38 degrees North-Easterly.

S C H O L I U M.

The angle of position between two places is a different thing from what is meant by the bearings of places; the *Bearings* of two places is determined by a sort of spiral line, called a *Rhumb Line*, passing between them in such a manner, as to make the same or equal angles with all the meridians through which it passeth; but the *angle of position* is the very same thing with what we call the azimuth in astronomy, both being formed by the meridian and a great circle passing thro' the zenith of a given place in the heavens, then called the azimuth, or upon the Earth, then called the angle of position.

From hence may be shewed the error of that geographical paradox, *viz.* If a place A bears from another B due West, B shall not bear from A due East. I find this paradox vindicated by an author, who at the same time gives a true definition of a rhumb line: But his arguments are ungeometrical; for if it be admitted that the East and West lines make the same angles with all the meridians through which they pass, it will follow that these lines are

the parallels of latitude: For any parallel of latitude is the continuation of the surface of a *Cone*, whose sides are the radii of the sphere, and circumference of its base the said parallel; and it is evident, that all the meridians cut the said surface at right (and therefore at equal) angles; whence it follows, that the rhumbs of East and West are the parallels of latitude, though the case may seem different, when we draw inclining lines (like meridians) upon paper, without carrying our ideas any farther.

PROB. IX. *To find the Antœci, Periœci, and Antipodes to any given place.*

Bring the given place to the meridian, and having found its latitude, count the same number of degrees on the meridian from the equator towards the contrary Pole, and that will give the place of the *Antœci*. The globe being still in the same position, set the hour index to XII at noon, then turn the globe about 'till the index points to the lower XII; the place which then lies under the meridian, having the same latitude with the given place, is the *Periœci* required. As the globe now stands, the

Antipodes of the given place are under the same point of the meridian, that its *Antæci* stood before: Or, if you reckon 180 degrees upon the meridian from the given place, that point will be the *Antipodes*. Let the given place be *London*, in the latitude of $51 \frac{1}{2}$ degrees North, that place which lies under the same meridian, and the latitude $51 \frac{1}{2}$ degrees South, is the *Antæci*; that which lies in the same parallel with *London*, and 180 degrees of longitude from it, is the *Periæci*, and the *Antipodes* is the place whose longitude from *London* is 180 degrees, and latitude $51 \frac{1}{2}$ degrees South.

PROB. X. *The Hour of the Day at one place being given; to find the correspondent Hour (or what o'Clock it is at that time) in any other place.*

The difference of time betwixt two places is the same with their difference of longitude; wherefore having found their difference of longitude, reduced into time (by allowing one hour for every 15 degrees, &c.) and if the place where the hour is required lies

{ Easterly }
 { Westerly } from the place where the
 8 hour

hour is given, $\left\{ \begin{array}{l} \text{add} \\ \text{subtract} \end{array} \right\}$ the difference of longitude reduced into time $\left\{ \begin{array}{l} \text{to} \\ \text{from} \end{array} \right\}$ the hour given; and the sum or remainder will accordingly be the hour required. Or,

Having brought the place at which the hour is given to the meridian, set the hour index to the given hour; then turn the globe about until the place where the hour is required comes to the meridian, and the index will point out the hour at the said place.

Thus when it is *Noon* at *London*, it is

		H.	M.	
At	{	<i>Rome</i>	- - - -	0 50 P. M.
		<i>Constantinople</i>	-	1 56 P. M.
		<i>Vera-Cruz</i>	- -	6 30 A. M.
		<i>Pekin in China</i>	-	7 46 P. M.

PROB. XI. *The Day of the Month being given, to find those places on the globe where the Sun will be Vertical, or in the Zenith, that day.*

Having found the Sun's place in the ecliptic, bring the same to the meridian, and note the degree over it; then turn-

ing the globe round, all places that pass under that degree will have the Sun vertical that day.

PROB. XII. *A place being given in the Torrid Zone, to find those two Days in which the Sun shall be Vertical to the same.*

Bring the given place to the meridian, and mark what degree of latitude is exactly over it; then turning the globe about its axis, those two points of the ecliptic, which pass exactly under the said mark, are the Sun's place; against which, upon the wooden horizon, you'll have the days required.

PROB. XIII. *To find where the Sun is Vertical at any given time assigned; or the Day of the Month and the Hour at any Place (suppose London) being given, to find in what place the Sun is Vertical at that very time.*

Having found the Sun's declination, and brought the first place (*London*) to the meridian, set the index to the given hour, then turn the globe about until the index points to XII at noon; which being done, that place upon the globe
which

which stands under the point of the Sun's declination upon the meridian, has the Sun that moment in the Zenith.

PROB. XIV. *The Day, and the Hour of the Day at one place, being given; to find all those places upon the Earth, where the Sun is then Rising, Setting, Culminating (or on the meridian) also where it is Day-light, Twilight, Dark Night, Midnight; where the Twilight then begins, and where it ends; the height of the Sun in any part of the illuminated hemisphere; also his depression in the obscure hemisphere.*

Having found the place where the Sun is vertical at the given hour, rectify the globe for that latitude, and bring the said place to the meridian.

Then all those places that are in the Western semicircle of the horizon, have the Sun rising at that time.

Those in the Eastern semicircle have it setting.

To those who live under the upper semicircle of the meridian, it is 12 o'clock at noon. And,

I 3

Those

Those who live under the lower semicircle of the meridian, have midnight.

All those places that are above the horizon, have the Sun above them, just so much as the places themselves are distant from the horizon; which height may be known by fixing the quadrant of altitude in the zenith, and laying it over any particular place.

In all those places that are 18 degrees below the Western side of the horizon, the twilight is just beginning in the morning, or the day breaks. And in all those places that are 18 degrees below the Eastern side of the horizon, the twilight is ending, and the total darkness beginning.

The twilight is in all those places whose depression below the horizon does not exceed 18 degrees. And,

All those places that are lower than 18 degrees, have dark night.

The depression of any place below the horizon is equal to the altitude of its *Antipodes*, which may be easily found by the quadrant of altitude. PROB.

PROB. XV. *The Day of the Month being given; to shew, at one view, the length of Days and Nights in all places upon the Earth at that time; and to explain how the vicissitudes of Day and Night are really made by the motion of the Earth round her axis in 24 hours, the Sun standing still.*

The Sun always illuminates one half of the globe, or that hemisphere which is next towards him, while the other remains in darkness: And if (as by the last problem) we elevate the globe according to the Sun's place in the ecliptic, it is evident, that the Sun (he being at an immense distance from the Earth) illuminates all that hemisphere, which is above the horizon; the wooden horizon itself, will be the circle terminating light and darkness; and all those places that are below it, are wholly deprived of the solar light.

The globe standing in this position, those arches of the parallels of latitude which stand above the horizon, are the *Diurnal Arches*, or the length of the day in all those latitudes at that time of the year; and the remaining parts of those parallels, which are below the

horizon, are the *Nocturnal Arches*, or the length of the night in those places. The length of the diurnal arches may be found by counting how many hours are contained between the two meridians, cutting any parallel of latitude, in the Eastern and Western parts of the horizon.

In all those places that are in the Western semicircle of the horizon, the Sun appears rising: For the Sun, standing still in the vertex (or above the brass meridian) appears Easterly, and 90 degrees distant from all those places that are in the Western semicircle of the horizon; and therefore in those places he is then rising. Now, if we pitch upon any particular place upon the globe, and bring it to the meridian, and then bring the hour index to the lower 12, which in this case we'll suppose to be 12 at noon; (because otherwise the numbers upon the hour circle will not answer our purpose) and afterwards turn the globe about until the aforesaid place be brought to the Western side of the horizon; the index will then shew the time of the Sun rising in that place. Then turn the globe gradually about from West to East, and minding the hour index, we shall see the progress made in the
day

day every hour, in all latitudes upon the globe, by the real motion of the Earth round its axis; until, by their continual approach to the brass meridian (over which the Sun stands still all the while) they at last have noon day, and the Sun appears at the highest; and then by degrees, as they move Easterly the Sun seems to decline Westward, until, as the places successively arrive in the Eastern part of the horizon, the Sun appears to set in the Western: For the places that are in the horizon, are 90 degrees distant from the Sun. We may observe, that all places upon the Earth, that differ in latitude, have their days of different length (except when the Sun is in the equinoctial) being longer or shorter, in proportion to what part of the parallels stands above the horizon. Those that are in the same latitude, have their days of the same length; but have them commence sooner or later, according as the places differ in longitude.

PROB. XVI. *To explain in general the alteration of Seasons, or length of the Days and Nights made in all places of the World, by the Sun's (or the Earth's) annual motion in the Ecliptic.*

It

It has been shewed in the last problem, how to place the globe in such a position as to exhibit the length of the diurnal and nocturnal arches in all places of the Earth, at a particular time: If the globe be continually rectified, according as the Sun alters his declination, (which may be known by bringing each degree of the ecliptic successively to the meridian) you'll see the gradual increase or decrease made in the days, in all places of the World, according as a greater or lesser portion of the parallels of latitude stands above the horizon. We shall illustrate this problem by examples taken at different times of the year.

1. Let the Sun be in the first point of φ (which happens on the 21st of *June*) that point being brought to the meridian, will shew the Sun's declination to be $23\frac{1}{2}$ degrees North; then the globe must be rectified to the latitude of $23\frac{1}{2}$ degrees; and for the better illustration of the problem, let the first meridian upon the globe be brought under the brass meridian. The globe being in this position, you'll see at one view the length of the days in all latitudes, by counting the number of hours contained
between

between the two extreme meridians, cutting any particular parallel you pitch upon, in the Eastern and Western part of the horizon. And you may observe that the lower part of the arctic circle just touches the horizon, and consequently all the people who live in that latitude have the Sun above their horizon for the space of 24 hours, without setting; only when he is in the lower part of the meridian (which they would call 12 at night) he just touches the horizon.

To all those who live between the arctic circle and the Pole, the Sun does not set, and its height above the horizon, when he is in the lower part of the meridian, is equal to their distance from the arctic circle: For example, Those who live in the 80th parallel have the Sun when he is lowest at this time $13\frac{1}{2}$ degrees high.

If we cast our eye Southward, towards the equator, we shall find, that the diurnal arches, or the length of days in the several latitudes, gradually lessen: The diurnal arch of the parallel of *London* at this time is $16\frac{1}{2}$ hours; that of the *Equator* (is always) 12 hours;
and

and so continually less, 'till we come to the *Antarctic Circle*, the upper part of which just touches the horizon; and those who live in this latitude have just one sight of the Sun, peeping as it were in the horizon: And all that space between the antarctic circle and the South Pole, lies in total darkness.

If from this position we gradually move the meridian of the globe according to the progressive alterations made in the Sun's declination, by his motion in the ecliptic, we shall find the diurnal arches of all those parallels, that are on the Northern side of the equator, continually decrease; and those on the Southern side continually increase, in the same manner as the days in those places shorten and lengthen. Let us again observe the globe when the Sun has got within 10 degrees of the equinoctial; now the lower part of the 80th parallel of North latitude just touches the horizon, and all the space betwixt this and the Pole, falls in the illuminated hemisphere: but all those parallels that lie betwixt this and the arctic circle, which before were wholly above the horizon, do now intersect it, and the Sun appears to them to rise and set.

From

From hence to the equator, we shall find that the days have gradually shortened; and from the equator Southward, they have gradually lengthened, until we come to the 80th parallel of the South latitude, the upper part of which just touches the horizon, and all places betwixt this and the South Pole are in total darkness; but those parallels betwixt this and the antarctic circle, which before were wholly below the horizon, are now partly above it; the length of their days being exactly equal to that of the nights in the same latitude in the contrary hemisphere. This also holds universally, that the length of one day in one latitude North, is exactly equal to the length of the night in the same latitude South; and *vice versa*.

Let us again follow the motion of the Sun, until he has got into the equinoctial, and take a view of the globe while it is in this position. Now all the parallels of latitude are cut into two equal parts by the horizon, and consequently the days and nights are of equal lengths, *viz.* 12 hours each, in all places of the world; the Sun rising and setting at six o'clock, excepting under the two *Poles*, which now lie exactly
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in the horizon: Here the Sun seems to stand still in the same point of the heavens for some time, until by degrees, by his motion in the ecliptic, he ascends higher to one, and disappears to the other, there being properly no days and nights under the Poles; for there the motion of the Earth round its axis cannot be observed.

If we follow the motion of the Sun towards the Southern tropic, we shall see the diurnal arches of the Northern parallels continually decrease, and the Southern ones increase in the same proportion, according to their respective latitudes; the North Pole continually descending, and the South Pole ascending, above the horizon, until the Sun arrives into ϖ , at which time all the space within the antarctic circle is above the horizon; while the space between the arctic circle and its neighbouring Pole, is in total darkness. And we shall now find all other circumstances quite reverse to what they were when the Sun was in φ ; the nights all over the world being of the same length that the days were of before.

We have now got to the extremity of the Sun's declination; and if we follow him through the other half of the ecliptic, and rectify the globe accordingly, we shall find the seasons return in their order, until at length we bring the globe into its first position.

The two foregoing problems were not, as I know of, published in any book on this subject before; and I have dwelt the longer upon them, because they very well illustrate how the vicissitudes of days and nights are made all over the world, by the motion of the Earth round her axis; the horizon of the globe being made the circle, separating light and darkness, and so the Sun to stand still in the vertex. And if we really could move the meridian, according to the change of the Sun's declination, we should see, at one view, the continual change made in the length of days and nights, in all places on the Earth; but as globes are fitted up, this cannot be done; neither are they adapted for the common purposes in places near the equator, or any where in the Southern hemisphere. But this inconvenience is now remedied (at a small additional expence) by the hour circle being

being made to shift to either Pole; and some globes are now made with an hour circle fixed to the globe at each Pole between the globe and meridian, so as to have none without side to interrupt the meridian from moving quite round the wooden horizon.

PROB. XVII. *To shew by the globe, at one view, the longest of the Days and Nights in any particular places, at all times of the Year.*

Because the Sun, by his motion in the ecliptic, alters his declination a small matter every day, if we suppose all the torrid zone to be filled up with a spiral line, having so many turnings; or a screw having so many threads, as the Sun is days in going from one tropic to the other; and these threads at the same distance from one another in all places, as the Sun alters his declination in one day in all those places respectively: This spiral line or screw will represent the apparent paths described by the Sun round the Earth every day; and by following the thread from one tropic to the other, and back again, we shall have the path the Sun seems to describe round the Earth in a year. But because the inclinations of

these threads to one another are but small, we may suppose each diurnal path to be one of the parallels of latitude, drawn, or supposed to be drawn, upon the globe. Thus much being premised, we shall explain this *Problem*, by placing the globe according to some of the most remarkable positions of it, as before we did for the most remarkable seasons of the year.

In the preceding problem, the globe being rectified according to the Sun's declination, the upper parts of the parallels of latitude represented the *Diurnal Arches*, or the length of the days all over the world, at that particular time: Here we are to rectify the globe according to the latitude of the place, and then the upper parts of the parallels of declination are the diurnal arches; and the length of the days at all times of the year, may be here determined, by finding the number of hours contained between the two extreme meridians, which cut any parallel of declination in the Eastern and Western points of the horizon; after the same manner as before we found the length of the day in the several latitudes at a particular time of the year.

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1. Let

1. Let the place proposed be under the equinoctial, and let the globe be accordingly rectified in 00 degrees of latitude, which is called a direct position of the sphere. Here all the parallels of latitude, which in this case we will call the parallels of declination, are cut by the horizon into two equal parts; and consequently those who live under the equinoctial, have the days and nights of the same length at all times of the year; and also in this part of the Earth, all the *Stars* rise and set, and their continuance above the horizon, is equal to their stay below it, *viz.* 12 hours.

If from this position we gradually move the globe according to the several alterations of latitudes, which we will suppose to be Northerly; the lengths of the *Diurnal Arches* will continually increase, until we come to a parallel of declination, as far distant from the equinoctial, as the place itself is from the Pole. This parallel will just touch the horizon, and all the heavenly bodies that are betwixt it and the Pole never descend below the horizon. In the mean time, while we are moving the globe, the lengths of the diurnal arches of the Southern parallels of declination, continually diminish,

diminish, in the same proportion that the Northern ones increased; until we come to that parallel of declination which is so far distant from the equinoctial Southerly, as the place itself is from the North Pole. The upper part of this *Parallel* just touches the horizon, and all the Stars that are betwixt it and the South Pole never appear above the horizon. And all the nocturnal arches of the Southern parallels of declination, are exactly of the same length with the diurnal arches of the correspondent parallels of North declination.

2. Let us take a view of the globe when it is rectified for the latitude of *London*, or $51\frac{1}{2}$ degrees North. When the Sun is in the tropic of ϖ , the day is about $16\frac{1}{2}$ hours; as he recedes from this tropic, the days proportionably shorten, until he arrives into ν , and then the days are at the shortest, being now of the same length with the night when the Sun was in ϖ , *viz.* $7\frac{1}{2}$ hours. The lower part of that parallel of declination, which is $38\frac{1}{2}$ degrees from the equinoctial Northerly, just touches the horizon; and the Stars that are betwixt this parallel and the North Pole, never set to us at *London*. In like man-

ner the upper part of the Southern parallel of $38\frac{1}{2}$ degrees just touches the horizon, and the Stars that lie betwixt this parallel and the Southern Pole, are never visible in this latitude.

Again, let us rectify the globe for the latitude of the *Arctic Circle*, we shall then find, that when the Sun is in ϖ , he touches the horizon on that day without setting, being 24 hours compleat above the horizon; and when he is in *Capricorn*, he once appears in the horizon, but does not rise in the space of 24 hours: When he is in any other point of the ecliptic, the days are longer or shorter, according to his distance from the tropics. All the Stars that lie between the tropic of *Cancer*, and the North Pole, never set in this latitude; and those that are between the tropic of *Capricorn* and the South Pole, are always hid below the horizon.

If we elevate the globe still higher, the circle of *perpetual Apparition* will be nearer the equator; as will that of *perpetual Occultation* on the other side. For example: Let us rectify the globe for the latitude of 80 degrees North: When the Sun's declination is 10 degrees

grees North; he begins to turn above the horizon without setting; and all the while he is making his progress from this point to the tropic of φ , and back again, he never sets. After the same manner, when his declination is 10 degrees South, he is just seen at noon in the horizon; and all the while he is going Southward, and back again, he disappears, being hid just so long as before, at the opposite time of the year he appeared visible.

Let us now bring the North Pole into the Zenith, then will the equinoctial coincide with the horizon; and consequently all the Northern parallels are above the horizon, and all the Southern ones below it. Here is but one day and one night throughout the year, it being day all the while the Sun is to the Northward of the equinoctial, and night for the other half year. All the Stars that have North declination, always appear above the horizon, and at the same height; and all those that are on the other side, are never seen.

What has been here said of rectifying the globe to North latitude, holds for the same latitude South; only that

before the longest days were, when the Sun was in ϖ , the same happening now when the Sun is in ν ; and so of the rest of the parallels, the seasons being directly opposite to those who live in different hemispheres.

I shall again explain some things delivered above in general terms, by particular problems.

But from what has been already said, we may first make the following observations :

1. *All places of the Earth do equally enjoy the benefit of the Sun, in respect of time, and are equally deprived of it, the Days at one time of the Year, being exactly equal to the Nights at the opposite season.*

2. *In all places of the Earth, save exactly under the Poles, the Days and Nights are of equal length (viz. 12 hours each) when the Sun is in the equinoctial.*

3. *Those who live under the equinoctial, have the days and nights of equal lengths at all times of the year.*

4. *In all places between the equinoctial
and*

and the Poles, the days and nights are never equal, but when the Sun is in the equinoctial points ϖ and \sphericalangle .

5. *The nearer any place is to the equator, the less is the difference between the length of the artificial days and nights in the said place; and the more remote the greater.*

6. *To all the inhabitants lying under the same parallel of latitude, the days and nights are of equal lengths, and that at all times of the year.*

7. *The Sun is vertical twice a year to all places between the tropics; to those under the tropics, once a year; but never any where else.*

8. *In all places between the Polar Circles, and the Poles, the Sun appears some number of days without setting; and at the opposite time of the year he is for the same length of time without rising; and the nearer unto, or further remote from the Pole, those places are, the longer or shorter is the Sun's continued presence or absence from the Pole.*

9. *In all places lying exactly under the Polar Circles, the Sun, when he is in*

the nearest tropic, appears 24 hours without setting; and when he is in the contrary tropic, he is for the same length of time without rising; but at all other times of the year, he rises and sets there, as in other places.

10. In all places lying in the $\left\{ \begin{array}{l} \text{Northern} \\ \text{Southern} \end{array} \right\}$ hemisphere, the longest day and shortest night, is when the Sun is in the $\left\{ \begin{array}{l} \text{Northern} \\ \text{Southern} \end{array} \right\}$ tropic; and on the contrary.

PROB. XVIII. *The Latitude of any place, not exceeding $66\frac{1}{2}$ degrees, and the day of the Month being given; to find the time of Sun-rising and setting, and the length of the Day and Night.*

Having rectified the globe according to the latitude, bring the Sun's place to the meridian, and put the hour index to 12 at noon; then bring the Sun's place to the Eastern part of the horizon, and the index will shew the time when the Sun rises. Again, turn the globe until the Sun's place be brought to the Western side of the horizon, and the index will shew the time of Sun-setting.

The hour of Sun-setting doubled, gives the length of the day; and the hour of Sun-rising doubled, gives the length of the night.

Let it be required to find when the Sun rises and sets at *London* on the 20th of *April*. Rectify the globe for the latitude of *London*, and having found the Sun's place corresponding to *May* the 1st, *viz.* $10\frac{3}{4}$ degrees of ϑ , bring $10\frac{3}{4}$ degrees of ϑ to the meridian, and set the index to 12 at noon; then turn the globe about 'till $10\frac{3}{4}$ degrees of ϑ be brought to the Eastern part of the horizon, and you'll find the index point to $4\frac{3}{4}$ hours, this being doubled, gives the length of the night $9\frac{1}{2}$ hours. Again, bring the Sun's place to the Western part of the horizon, and the index will point to $7\frac{1}{4}$ hours, which is the time of Sun-setting; this being doubled, gives the length of the day $14\frac{1}{2}$ hours.

PROB. XIX. *To find the length of the longest and shortest Day and Night in any given place, not exceeding $66\frac{1}{4}$ degrees of Latitude.*

Note, The longest day at all places on the $\left\{ \begin{array}{l} \text{North} \\ \text{South} \end{array} \right\}$ side of the equator, is when
the

the Sun is in the first point of $\left\{ \begin{array}{l} \text{Cancer.} \\ \text{Capricorn.} \end{array} \right.$

Wherefore having rectified the globe for the latitude, find the time of Sun-rising and setting, and thence the length of the day and night, as in the last problem, according to the place of the Sun: Or, having rectified the globe for the latitude, bring the solstitial point of that hemisphere, to the East part of the horizon, and set the index to 12 at noon; then turning the globe about 'till the said solstitial point touches the Western side of the horizon, the number of hours from noon to the place where the index points (being counted according to the motion of the index) is the length of the longest day; the complement whereof to 24 hours, is the length of the shortest night, and the reverse gives the shortest day and the longest night.

	<i>Longest Day.</i>		<i>Shor. N.</i>
	<i>Deg.</i>	<i>Hours.</i>	<i>Hours.</i>
Thus in Lat.	{	45 . .	$15\frac{1}{2}$ $8\frac{1}{2}$
	{	$51\frac{1}{2}$. .	$16\frac{1}{2}$ $7\frac{1}{2}$
	{	60 . .	$18\frac{1}{2}$ $5\frac{1}{2}$

If from the length of the longest day, you subtract 12 hours, the number of
half

half hours remaining, will be the *Climate*: Thus that place where the longest day is $16\frac{1}{2}$ hours, lies in the 9th *Climate*. And by the reverse, having the *Climate*, you have thereby the length of the longest day.

PROB. XX. *To find in what Latitude the longest Day is, of any given length, less than 24 hours.*

Bring the solstitial point to the meridian, and set the index to 12 at noon; then turn the globe Westward, 'till the index points at half the number of hours given; which being done, keep the globe from turning round its axis, and slide the meridian up or down in the notches, 'till the solstitial point comes to the horizon, then that elevation of the Pole will be the latitude.

If the hours given be 16, the latitude is 49 degrees; if 20 hours, the latitude is $63\frac{1}{4}$ degrees.

PROB. XXI. *A place being given in one of the Frigid Zones (suppose the Northern) to find what number of Days (of 24 hours each) the Sun doth constantly shine upon the same, how long he is absent, and also the first and last Day of his appearance.*

Having rectified the globe according to the latitude, turn it about until some point in the first quadrant of the ecliptic (because the latitude is North) intersects the meridian in the North point of the horizon; and right against that point of the ecliptic on the horizon, stands the day of the month when the longest day begins.

And if the globe be turned about 'till some point in the second quadrant of the ecliptic cuts the meridian in the same point of the horizon, it will shew the Sun's place when the longest day ends, whence the day of the month may be found, as before: Then the number of natural days contained between the times the longest day begins and ends, is the length of the longest day required.

Again

Again, turn the globe about, until some point in the third quadrant of the ecliptic cuts the meridian in the South part of the horizon; that point of the ecliptic will give the time when the longest night begins. Lastly, turn the globe about, until some point in the fourth quadrant of the ecliptic cuts the meridian in the South point of the horizon; and that point of the ecliptic will be the place of the Sun when the longest night ends.

Or, the time when the longest day or night begins, being known, their end may be found by counting the number of days from that time to the succeeding solstice; then counting the same number of days from the solstitial day, will give the time when it ends.

PROB. XXII. *To find in what Latitude the longest Day is, of any given length less than 182 Natural Days.*

Find a point in the ecliptic half so many degrees distant from the solstitial point, as there are days given, and bring that point to the meridian; then keep the globe from turning round its axis,
and

and move the meridian up or down until the aforesaid point of the ecliptic comes to the horizon; that elevation of the Pole will be the latitude required.

If the days given were 78, the latitude is $71\frac{1}{2}$ degrees.

This method is not accurate, because the degrees in the ecliptic do not correspond to natural days; and also because the Sun does not always move in the ecliptic at the same rate; however, such problems as these may serve for amusement.

PROB. XXIII. *The day of the Month being given, to find when the Morning and Evening Twilight begins and ends, in any place upon the Globe,*

In the foregoing problem, by the length of the day, we mean the time from Sun-rising to Sun-set; and the night we reckoned from Sun-set, 'till he rose next morning. But it is found by experience, that *Total Darkness* does not commence in the evening, 'till the Sun has got 18 degrees below the horizon; and when he comes within the same distance of the horizon next morning,

ing,

ing, we have the first *Dawn of Day*. This faint light which we have in the morning and evening, before and after the Sun's rising and setting, is what we call the *Twilight*.

* Having rectified the globe for the latitude, the zenith, and the Sun's place, turn the globe and the quadrant of altitude until the Sun's place cuts 18 degrees below the horizon (if the quadrant reaches so far) then the index upon the hour circle will shew the beginning or ending of twilight after the same manner as before we found the time of the Sun-rising and setting, in *Prob. 18*. But by reason of the thickness of the wooden horizon, we can't conveniently see, or compute when the Sun's place is brought to the point aforesaid. Wherefore the globe being rectified as above directed, turn the globe, and also the quadrant of altitude, Westward, until that point in the ecliptic, which is opposite to the Sun's place, cuts the quadrant in the 18th degree above the horizon; then the hour index will shew the time when day breaks in the morning. And if you turn the globe and the quadrant of altitude, until the point opposite to the Sun's

Sun's place cuts the quadrant in the Eastern hemisphere, the hour hand will shew when twilight ends in the evening. Or, having found the time from midnight when the morning twilight begins, if you reckon so many hours before midnight, it will give the time when the evening twilight ends. Having found the time when twilight begins in the morning, find the time of Sun-rising, by *Prob. 18*, and the difference will be the duration of twilight.

Thus at *London*, on the 12th of *May*, twilight begins at three quarters past one o'clock: The Sun rises at about half an hour past four: Whence the duration of twilight now is $2\frac{3}{4}$ hours, both in the morning and evening. On the 12th of *November*, the twilight begins about half an hour before six, being about two hours before Sun-rising.

PROB. XXIV. To find the time when total Darkness ceases, or when the Twilight continues from Sun-setting to Sun-setting, in any given place.

Let the place be in the Northern hemisphere; then if the complement of
the

the latitude be greater than (the depression (18 degrees, subtract 18 degrees from it, and the remainder will be the Sun's declination North, when total darkness ceases. But if the complement of the latitude is less than 18 degrees, their difference will be the Sun's declination South, when the twilight begins to continue all night. If the latitude is South, the only difference will be, that the Sun's declination will be on the contrary side.

Thus at *London*, when the Sun's declination North is greater than $20\frac{1}{2}$ degrees, there is no total darkness, but constant twilight, which happens from the 26th of *May* to the 21st of *July*, being near two months. Under the North Pole the twilight ceases, when the Sun's declination is greater than 18 degrees South, which is from the 13th of *November*, 'till the 29th of *January*: So that notwithstanding the Sun is absent in this part of the world for half a year together, yet total darkness does not continue above 11 weeks; and besides, the *Moon* is above the horizon for a whole fortnight of every month throughout the year.

PROB. XXV. *The day of the Month being given; to find those places of the Frigid Zones, where the Sun begins to shine continually without setting; and also those places where he begins to be totally absent.*

Bring the Sun's place to the meridian, and mark the number of degrees contained betwixt that point and the equator; then count the same number of degrees from the nearest Pole (*viz.* the North Pole, if the Sun's declination is Northerly, otherwise the South Pole) towards the equator, and note that point upon the meridian; then turn the globe about, and all the places which pass under the said point, are those where the Sun begins to shine constantly, without setting on the given day. If you lay the same distance from the opposite Pole towards the equator, and turn the globe about, all the places which pass under that point will be those where the it begins then to be constant night.

The Latitude of the place being given, to find the hour of the day when he Sun shines.

If

If it be in the summer, elevate the Pole according to the latitude, set the meridian due North and South, and the frame of the globe truly horizontal; then the shadow of the axis will cut the hour on the Dial-plate: For the globe being rectified in this manner, the hour circle is a true *Equinoctial Dial*; the axis of the globe being the *Gnomon*. This holds true in *Theory*, but it might not be very accurate in practice, because of the difficulty in placing the horizon of the globe truly horizontal, and its meridian due North and South.

If it be in the winter half year, elevate the South Pole according to the latitude North, and let the North part of the horizon be in the South part of the meridian; then the shade of the axis will show the hour of the day as before: But this cannot be so conveniently performed, tho' the reason is the same as in the former case.

To find the Sun's altitude, when it shines, by the Globe.

Having set the frame of the globe truly horizontal or level, turn the North Pole towards the Sun, and move the meridian up or down in the notches,

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until

until the axis casts no shadow ; then the arch of the meridian, contained betwixt the Pole and the horizon, is the Sun's altitude.

Note, The best way to find the Sun's altitude, is by a little quadrant graduated into degrees, and having sights and a plummet to it: Thus, hold the quadrant in your hand, so as the rays of the Sun may pass through both the sights, the plummet then hanging freely by the side of the instrument, will cut in the limb the altitude required. These quadrants are to be had at the instrument-makers, with lines drawn upon them, for finding the hour of the day, and the azimuth; with several other pretty conclusions, very entertaining for beginners.

The Latitude and the Day of the Month being given, to find the hour of the day when the Sun shines.

Having placed the wooden frame upon a level, and the meridian due North and South, rectify the globe for the latitude, and fix a needle perpendicularly over the Sun's place: The Sun's place being brought to the meridian, set the
 3 hour

hour index at 12 at noon, then turn the globe about until the needle points exactly to the Sun, and casts no shadow, and then the index will shew the hour of the day.

PROB. XXVI. *The Latitude, the Sun's Place, and his Altitude, being given; to find the hour of the Day, and the Sun's Azimuth from the Meridian.*

Having rectified the globe for the latitude, the zenith, and the Sun's place, turn the globe and the quadrant of altitude, so that the Sun's place may cut the given degree of altitude: then the index will show the hour, and the quadrant will cut the azimuth in the horizon. Thus, if at *London*, on the 21st of *August*, the Sun's altitude, be 36 degrees in the forenoon, the hour of the day will be IX, and the Sun's azimuth about 58 degrees from the South part of the meridian.

The Sun's Azimuth being given, to place the Meridian of the Globe due North and South, or to find a Meridian Line when the Sun shines.

Let the Sun's azimuth be 30 degrees South-Easterly, set the horizon of the globe upon a level, and bring the North Pole into the zenith; then turn the horizon about until the shade of the axis cuts as many hours as is equivalent to the azimuth (allowing 15 degrees to an hour) in the North-West part of the hour circle, *viz.* X at night, which being done, the meridian of the globe stands in the true meridian of the place. The globe standing in this position, if you hang two plummets at the North and South points of the wooden horizon, and draw a line betwixt them, you will have a meridian line; which if it be on a fixed plane (as a floor or window) it will be a guide for placing the globe due North and South, at any other time.

PROB. XXVII. *The Latitude, Hour of the Day, and the Sun's place being given, to find the Sun's Altitude and Azimuth.*

Rectify the globe for the latitude, the zenith, and the Sun's place, then the number of degrees contained betwixt the Sun's place and the vertex, is the Sun's meridional zenith distance; the com-

complement of which to 90 degrees, is the Sun's meridian altitude. If you turn the globe about until the index points to any other given hour, then bringing the quadrant of altitude to cut the Sun's place, you will have the Sun's altitude at that hour; and where the quadrant cuts the horizon, is the Sun's azimuth at the same time. Thus *May* the 1st at *London*, the Sun's meridian altitude will be $53\frac{1}{2}$ degrees; and at 10 o'clock in the morning, the Sun's altitude will be 46 degrees, and his azimuth about 46 degrees from the South part of the meridian.

PROB. XXVIII. *The Latitude of the place, and the day of the Month being given; to find the depression of the Sun below the Horizon, and the Azimuth at any Hour of the Night.*

Having rectified the globe for the latitude, the zenith, and the Sun's place, take a point in the ecliptic exactly opposite to the Sun's place, and find the Sun's altitude and azimuth, as by the last problem, and these will be the depression and the altitude required. Thus, the time given be the 1st of *November*, at 10 o'clock at night, the depression and

azimuth will be the same as was found in the last problem.

PROB. XXIX. *The Latitude, the Sun's Place, and his Azimuth being given, to find his Altitude, and the Hour.*

Rectify the globe for the latitude, the zenith, and the Sun's place, then put the quadrant of altitude to the Sun's azimuth in the horizon, and turn the globe 'till the Sun's place meet the edge of the quadrant, then the said edge will shew the altitude, and the index point to the hour. Thus, *May* the 21st at *London*, when the Sun is due East, his altitude will be about 24 degrees, and the hour about VII in the morning; and when his azimuth is 60 degrees South-Westerly, the altitude will be about $44\frac{1}{2}$ degrees, and the hour about $2\frac{3}{4}$ in the afternoon.

Thus, the latitude and the day being known, and having besides either the altitude, the azimuth, or the hour; the other two may be easily found.

PROB. XXX. *The Latitude, the Sun's Altitude, and his Azimuth being given; to find his Place in the Ecliptic and the Hour.*

Rectify

Rectify the globe for the latitude and zenith, and set the edge of the quadrant to the given azimuth; then turning the globe about, that point of the ecliptic which cuts the altitude, will be the Sun's place. Keep the quadrant of the altitude in the same position, and having brought the Sun's place to the meridian, and the hour index to 12 at noon, turn the globe about 'till the Sun's place cuts the quadrant of altitude, and then the index will point the hour of the day.

PROB. XXXI. *The Declination and Meridian Altitude of the Sun, or of any Star being given; to find the Latitude of the Place.*

Mark the point of declination upon the meridian, according as it is either North or South from the equator; then slide the meridian up or down in the notches, 'till the point of declination be so far distant from the horizon, as is the given meridian altitude; that elevation of the Pole will be the latitude.

Thus, if the Sun's, or any Star's meridian altitude be 50 degrees, and its de-

declination $11\frac{1}{2}$ degrees North, the latitude will be $51\frac{1}{2}$ degrees North.

PROB. XXXII. *The Day and Hour of a Lunar Eclipse being known; to find all those Places upon the Globe where the same will be visible.*

* *Prob.*
XIII. * Find where the Sun is vertical at the given hour, and bring that point to the zenith; then the Eclipse will be visible in all those places that are under the horizon: Or, if you bring the Antipodes to the place where the Sun is vertical, into the zenith, you will have the places where the Eclipse will be visible above the horizon.

Note, Because *Lunar* eclipses continue sometimes for a long while together, they may be seen in more places than one hemisphere of the Earth; for by the Earth's motion round its axis, during the time of the eclipse, the Moon will rise in several places after the eclipse began.

Note, When an eclipse of the Sun is central, if you bring the place where the Sun is vertical at that time, into the zenith, some part of the eclipse will be
visi-

visible in most places within the upper hemisphere; but by reason of the short duration of Solar eclipses, and the latitude which the Moon commonly has at that time (though but small) there is no certainty in determining the places where those eclipses will be visible by the globe; but recourse must be had to calculations.

PROB. XXXIII. *The Day of the Month, and Hour of the Day, according to our way of reckoning in England, being given; to find thereby the Babylonian, Italic, and the Jewish, or Judicial Hour.*

1. To find the *Babylonian Hour* (which is the number of hours from Sun-rising.) Having found the time of Sun-rising in the given place, the difference betwixt this and the hour given, is the *Babylonian Hour*.

2. To find the *Italic Hour* (which is the number of hours from Sun-setting. Subtract the hour of Sun-setting from the given hour, and the remainder will be the *Italic Hour* required.

3. To find the *Jewish Hour* (which is $\frac{7}{12}$ part of an *Artificial Day*.) Find how many
many

many hours the day consists of; then say, as the number of hours the day consists of is to 12 hours, so is the hour since Sun-rising to the *Judaical* hour required.

Thus, if the Sun rises at 4 o'clock (consequently sets at 8) and the hour given be 5 in the evening, the *Babylonish* hour will be the 13th, the *Italic* the 21st, and the *Jewish* hour will be nine and three quarters.

The converse being given, the hour of the day, according to our way of reckoning in *England*, may be easily found.

The following Problems are peculiar to the *Celestial Globe*,

PROB. XXXIV. *To find the Right Ascension and Declination of the Sun, or any Fixed Star.*

Bring the Sun's place in the ecliptic to the meridian; then that degree of the equator, which is cut by the meridian, will be the *Sun's Right Ascension*; and that degree of the meridian, which is exactly over the Sun's place, is the *Sun's Declination*. ●

After

After the same manner bring the place of any Fixed Star to the meridian, and you will find its Right Ascension in the equinoctial, and Declination of the meridian.

Thus the right ascension and declination is found, after the same manner as the longitude and latitude of a place upon the *Terrestrial Globe*.

Note, The right ascension and declination of the Sun vary every day; but the right ascension, &c. of the Fixed Stars is the same throughout the year *.

The Sun's Right Ascension. Declin.

		Deg.	Deg.
Thus on	{ January 31	314	17 $\frac{1}{2}$ S.
	{ April 5 -	14 $\frac{1}{4}$	6 N.
	{ July 21 -	120 $\frac{1}{4}$	20 $\frac{1}{2}$ N.
	{ November 26	242 $\frac{1}{4}$	21 S.
		R. Asc.	Decl.

		Deg.	Deg.
<i>Aldebaran</i>	— —	65 $\frac{3}{4}$	16 N.
<i>Spica Virginis</i>	— —	198 $\frac{1}{4}$	10 S.
<i>Capella</i>	— —	75	45 $\frac{1}{4}$ N.
<i>Syrius, or the Dog-Star</i>		98 $\frac{3}{4}$	16 $\frac{1}{2}$ S.

* The insensible change in the Longitude, Right Ascension, and Declination of the Fixed Stars, made by their slow motion, parallel to the ecliptic (being but 1 degree in 72 years) is not worth notice in this place.

Note,

Note, The declination of the Sun may be found after the same manner by the *Terrestrial Globe*, and also his right ascension, when the equinoctial is numbered into 360 degrees, commencing at the equinoctial point γ : But as the equinoctial is not always numbered so, and this being properly a Problem in *Astronomy*, we choose rather to place it here.

By the converse of this problem, having the right ascension and declination of any point given, that point itself may be easily found upon the globe.

PROB. XXXV. *To find the Longitude and Latitude of a given Star.*

Having brought the solstitial colure to the meridian, fix the quadrant of altitude over the proper Pole of the ecliptic, whether it be North or South; then turn the quadrant over the given Star, and the arch contained betwixt the Star and the ecliptic, will be the latitude, and the degree cut on the ecliptic will be the Star's longitude.

Thus the latitude of *Arcturus* will be found to be 31 degrees North, and the lon-

longitude 200 degrees from φ , or 20 degrees from ϵ : The latitude of *Fomaulhaut* in the Southern Fish, 21 degrees South, and longitude $299\frac{1}{2}$ degrees, or $29\frac{1}{2}$ degrees. By the converse of this method, having the latitude and longitude of a Star given, it will be easy to find the Star upon the globe.

The distance betwixt two Stars, or the number of degrees contained betwixt them, may be found by laying the quadrant of altitude over each of them, and counting the number of degrees intercepted; after the same manner as we found the distance betwixt two places on the *Terrestrial* Globe, in *Prob. VII.*

PROB. XXXVI. *The Latitude of the Place, the Day of the Month, and the Hour being given; to find what Stars are then rising or setting, what Stars are culminating, or on the meridian, and the Altitude and Azimuth of any Star above the Horizon; and also how to distinguish the Stars in the Heavens one from the other, and to know them by their proper Names.*

I

Having

Having rectified the globe for the latitude, the zenith, and the Sun's place, turn the globe about until the index points to the given hour, the globe being kept in this position.

All those Stars that are in the { Eastern }
 { Western }
 side of the horizon, are then { Rising, }
 { Setting. }

All those Stars that are under the meridian, are then culminating. And if the quadrant of altitude be laid over the center of any particular Star, it will show that Star's altitude at that time; and where it cuts the horizon, will be the Star's azimuth from the North or South part of the meridian.

The globe being kept in the same elevation, and from turning round its axis, move the wooden frame about until the North and South points of the horizon lie exactly in the meridian; then right lines imagined to pass from the center thro' each Star upon the surface of the globe, will point out the real Star in the heavens, which those on the globe are made to represent. And if you are by the side of some wall whose bearing you know

know, lay the quadrant of altitude to that bearing in the horizon, and it will cut all those Stars which at that very time are to be seen in the same direction, or close by the side of the said wall. Thus knowing some of the remarkable Stars in any part of the heavens, the neighbouring Stars may be distinguished by observing their situations with respect to those that are already known, and comparing them with the Stars drawn upon the globe.

Thus, if you turn your face towards the North, you will find the North Pole of the globe points to the *Pole-Star*; then you may observe two Stars somewhat less bright than the *Pole-Star*, almost in a right line with it, and four more which form a sort of *quadrangle*; these seven Stars make the constellation called the *Little Bear*; the *Pole-Star* being in the tip of the tail. In this neighbourhood you will observe seven bright Stars, which are commonly called *Charles's Wane*; these are the bright Stars in the *Great Bear*, and form much such another figure with those before-mentioned in the *little Bear*: The two foremost of the square lie almost in a right line with the *Pole Star*, and are called the *Pointers*; so that know-

M ing

ing the Pointers, you may easily find the Pole Star. Thus the rest of the Stars in this constellation, and all the Stars in the neighbouring constellations may be easily found, by observing how the unknown Stars lie either in *quadrangles, triangles,* or strait lines, from those that are already known upon the globe.

After the same manner the globe being rectified, you may distinguish those Stars that are to the Southward of you, and be soon acquainted with all the Stars that are visible in our hemisphere.

S C H O L I U M.

The globe being rectified to the latitude of any place, if you turn it round its axis, all those Stars that do not go below the horizon during a whole revolution of the globe, never set in that place; and those that do not come above the horizon never rise.

PROB. XXXVII. *The latitude of the place being given; to find the Amplitude, Oblique Ascension and Descension, Ascensional Difference, Semi-diurnal Arch, and the time of continuance above the horizon, of any given point in the heavens.*

Having

Having rectified the globe for the latitude, and brought the given point to the meridian, set the index to the hour of 12; then turn the globe until the given point be brought to the Eastern side of the horizon, and that degree of the equinoctial which is cut by the horizon at that time, will be the *Oblique Ascension*; and where the given point cuts the horizon, is the *Amplitude Ortive*: If the globe be turned about until the given point be brought to the Western side of the horizon, it will there show the *Amplitude Occasive*; and where the horizon cuts the equinoctial at that time, is the *Oblique Descension*.

The time between the index at either of these two positions, and the hour of 6; or half the difference between the oblique ascension and descension is the *Ascensional Difference*.

If the place be in North latitude and the declination of the given point be $\left\{ \begin{array}{l} \text{North} \\ \text{South} \end{array} \right.$ the ascensional difference reduced into time, and $\left\{ \begin{array}{l} \text{added to} \\ \text{subtracted from} \end{array} \right.$ 6 o'Clock, gives the *Semi-diurnal Arch*; the complement whereof to a semicircle, is the

Semi-nocturnal Arch. If the place be in South latitude, then the contrary is to be observed with respect to the declination.

The semi- $\left\{ \begin{array}{l} \text{diurnal} \\ \text{nocturnal} \end{array} \right\}$ arch being doubled, gives the time of continuance $\left\{ \begin{array}{l} \text{above} \\ \text{below} \end{array} \right\}$ the horizon. Or the time of continuance above the horizon, may be found by counting the number of hours contained in the upper part of the horary circle, betwixt the place where the index pointed when the given point was in the Eastern or Western parts of the horizon. If the given point was the Sun's place, the index pointed the time of his rising and setting, when the said place was in the Eastern and Western parts of the horizon, as in *Prob.* 18. Or the time of Sun-rising may be found by adding or subtracting his ascensional difference, to or from the hour of six, according as the latitude and declination are either contrary or the same way.

Thus, at *London*, on the 1st of *May*,
the *Sun's*

Amplitude is 24 degrees Northerly.

Oblique Ascension, 20.

Ob-

Oblique Descension, 58.

Ascensional Difference, 19.

Semidiurnal Arch, 109.

His continuance above the horizon,
14 $\frac{1}{2}$ hours.

Sun rises at three quarters past four.

Sun sets a quarter past seven.

These things for the Sun vary every day; but for a Fixed Star the day of the month need not be given, for they are the same all the year round.

In the latitude of 51 $\frac{1}{2}$ North, *Syrius's Amplitude* is about 28 degrees Southerly.

Oblique Ascension, 121.

Oblique Descension, 75.

Ascensional Difference, 23.

Semi-diurnal Arch, 67.

Continuance above the horizon, 9 hours.

PROB. XXXVIII. *The Latitude and the Day of the Month being given; to find the Hour when any known Star will be upon the meridian, and also the time of its rising and setting.*

Having rectified the globe for the latitude and the Sun's place, bring the given Star to the meridian, and also to the East

or West side of the horizon, and the index will shew accordingly when the Star *culminates*, or the time of the *rising* or *setting*.

Thus at *London*, on the 21st of *January*, *Syrius* will be upon the meridian, at a quarter past ten in the evening; rises at $5\frac{3}{4}$ hours, and sets at three quarters past two in the morning.

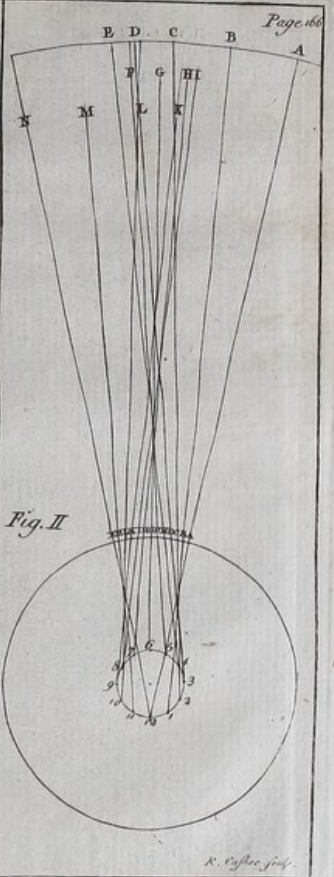
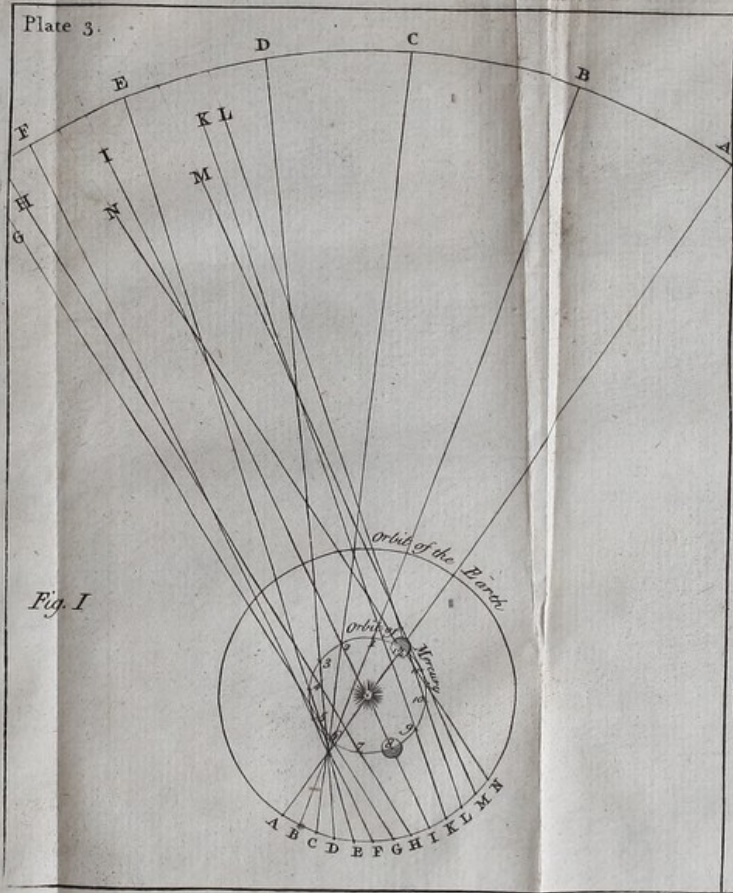
By the converse of this problem, knowing the time when any Star is upon the meridian, you may easily find the Sun's place. Thus, bring the given Star to the meridian, and set the index to the given hour; then turn the globe till the index points to 12 at noon, and the meridian will cut the Sun's place in the ecliptic. Thus when *Syrius* comes to the meridian at 10' hours after noon, the Sun's place will be $\approx 1\frac{3}{4}$ deg.

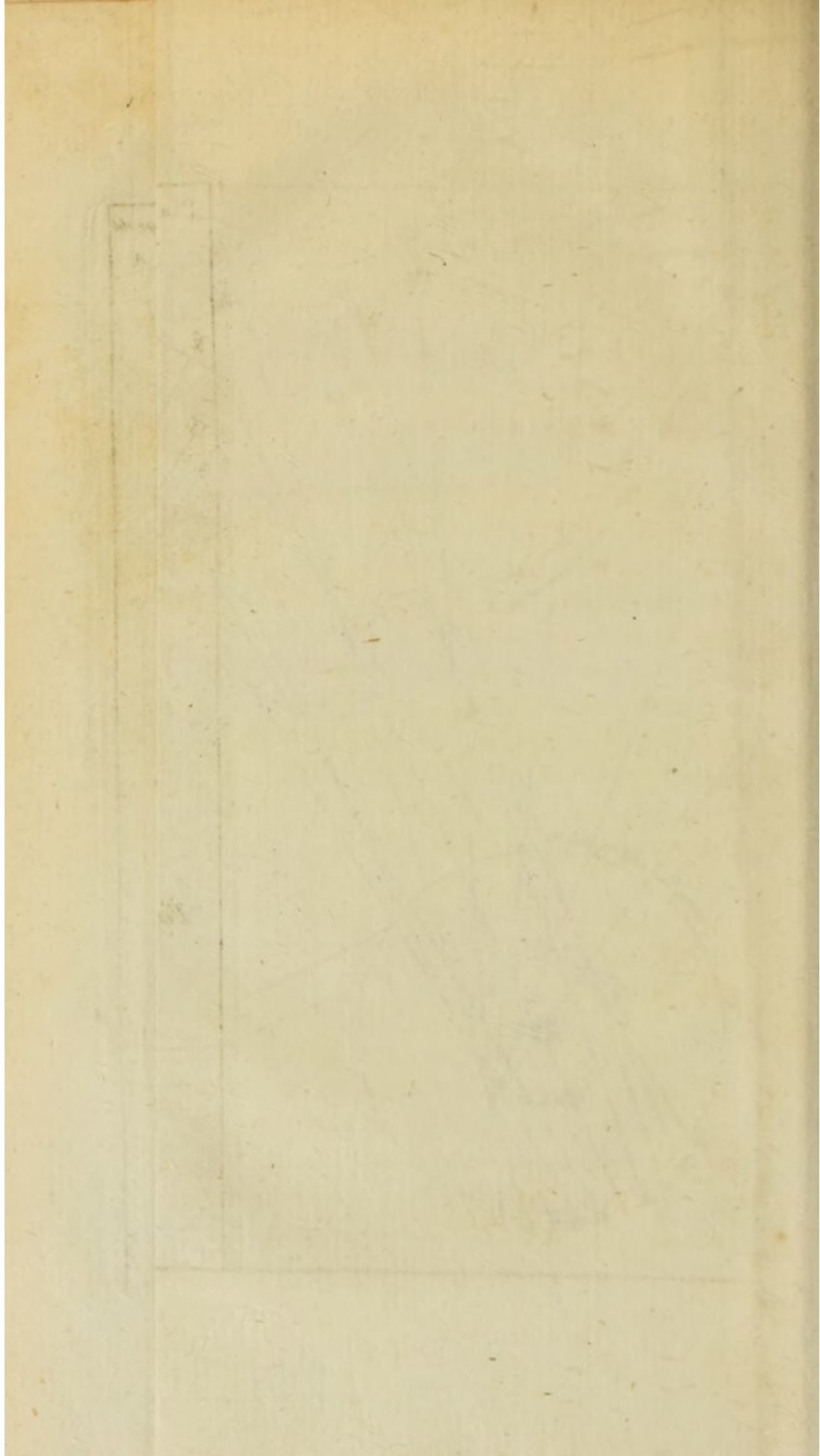
PROB. XXXIX. *To find at what time of the Year a given Star will be upon the Meridian, at a given Hour of the Night.*

Bring the Star to the meridian, and set the index to the given hour, then turn the globe till the index points to 12 at

3

noon,





noon, and the meridian will cut the ecliptic in the Sun's place; whence the day of the month may be easily found in the kalendar upon the horizon.

PROB. XL. *The Day of the Month, and the Azimuth of any known Star being given; to find the Hour of the Night.*

Having rectified the globe for the latitude and the Sun's place, if the given Star be due North or South, bring it to the meridian, and the index will show the hour of the night. If the Star be in any other direction, fix the quadrant of altitude in the zenith, and set it to the Star's azimuth in the horizon; then turn the globe about until the quadrant cuts the center of the Star, and the index will shew the hour of the night.

The bearing of any point in the heavens may be found by the following methods.

Having a meridian line drawn in two windows, that are opposite to one another, you may cross it at right angles with another line representing the East and West; from the point of the intersection describe a circle, and divide each

quadrant into 90 degrees; then get a smooth board, of about 2 feet long, and $\frac{3}{4}$ of a foot broad (more or less, as you judge convenient) and on the back part of it fix another small board crossways, so that it may serve as a foot to support the biggest board upright, when it is set upon a level, or an horizontal plane. The board being thus prepared, set the lower edge of the smooth, or fore side of it, close to the center of the circle, then turn it about to the meridian, or to any azimuth point required (keeping the edge of it always close to the center) and casting your eye along the flat side of it, you will easily perceive what Stars are upon the meridian, or any other bearing that the board is set to.

PROB. XLI. *Two known Stars having the same Azimuth, or the same Height, being given; to find the Hour of the Night.*

Rectify the globe for the latitude, the zenith, and the Sun's place.

1. When the two Stars are in the same azimuth, turn the globe, and also the quadrant about, until both Stars coincide with the edge thereof; then will the index shew the hour of the night; and

and where the quadrant cuts the horizon, is the common azimuth of both Stars.

2. If the two Stars are of the same altitude, move the globe so that the same degree on the quadrant will cut both Stars, then the index will shew the hour.

This problem is useful when the quantity of the azimuth of the two Stars in the first case, or of their altitude in the latter case, is not known,

If two Stars were given, one of the meridian, and the other in the East or West part of the horizon; to find the Latitude.

Bring that Star which was observed on the meridian, to the meridian of the globe, and keep the globe from turning round its axis; then slide the meridian up or down in the notches, till the other Star is brought to the East or West part of the horizon, and that elevation of the Pole will be the *Latitude* sought.

PROB. XLII. *The Latitude, Day of the Month, and the Altitude of any known Star being given; to find the Hour of the Night.*

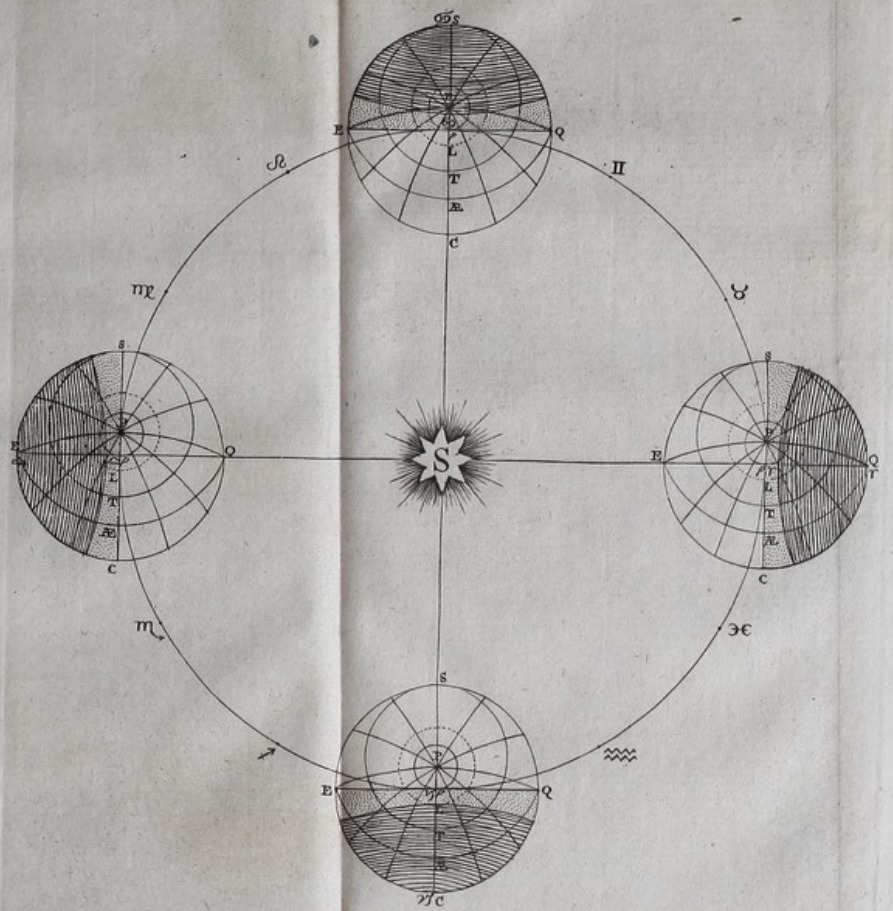
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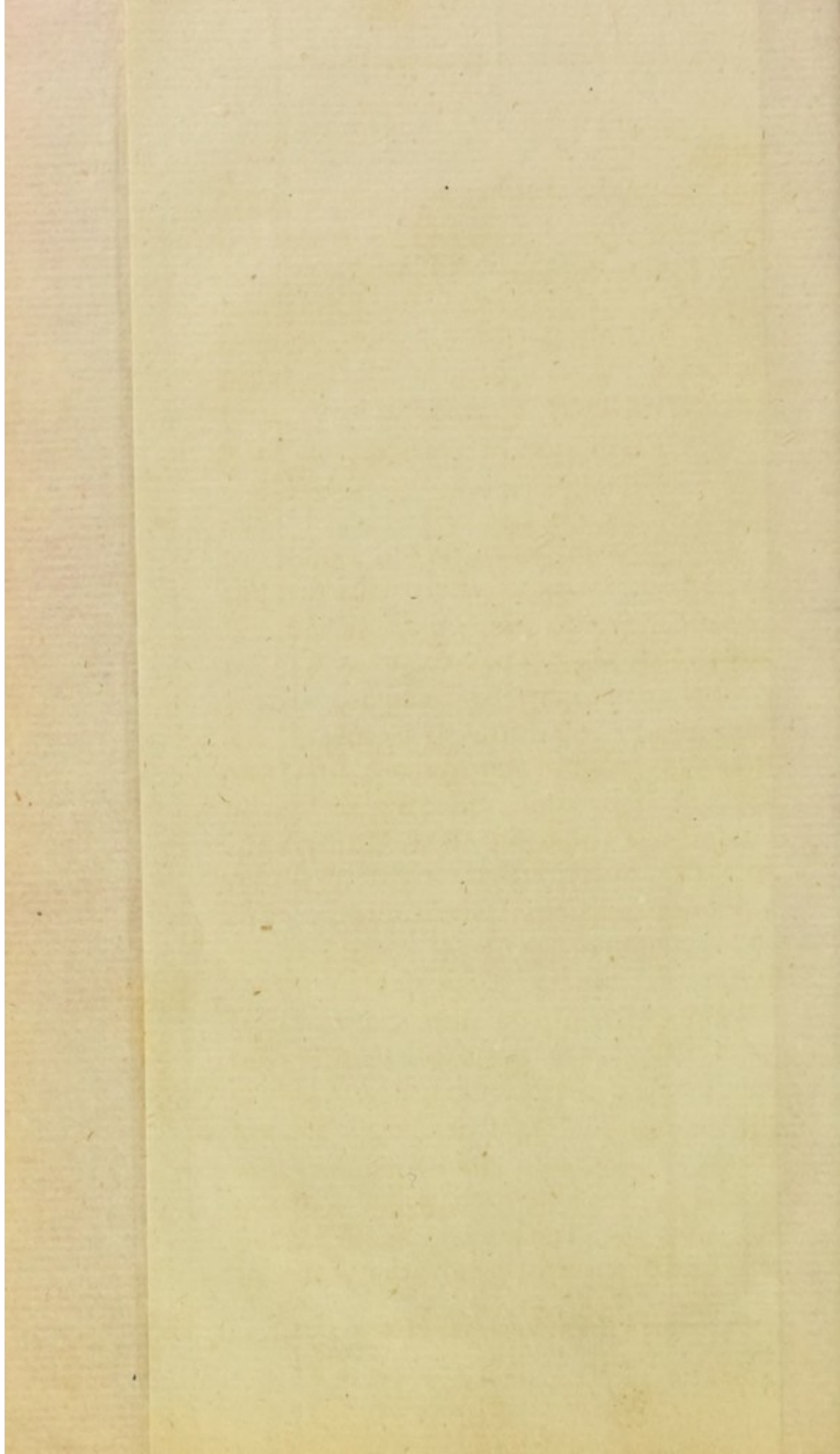
and if you bring it to the Eastern part of the horizon, that degree which sets at that time will be the Sun's place when the Star rises *Achronically*.

Thus, in the latitude of *London*, *Syrus*, or the *Dog-Star*, rises *Cosmically* the 10th of *August*, and sets *Cosmically* the 15th of *November*. *Aldebaran*, or the *Bull's Eye*, sets *Achronically* on the 22d of *May*, and rises *Achronically* on the 9th of *December*.

PROB. XLIV. *Having the Latitude of the place, to find the Time when a Star rises and sets Heliacally.*

Having rectified the globe for the latitude, bring the Star to the Eastern side of the horizon, and turn the quadrant round to the Western side, till it cuts the ecliptic in 12 degrees of altitude above the horizon, if the Star be of the first magnitude; then that point of the ecliptic which is cut by the quadrant, is 12 degrees high above the Western part of the horizon, when the Star rises; but at the same time the opposite point in the ecliptic is 12 degrees below the Eastern part of the horizon, which is the depression of a Star of the *first magnitude*, when





when it *rises Heliacally*; or has got so far from the Sun's beams, that it may be seen in the morning before Sun-rising. Wherefore look for the said point of the ecliptic on the horizon, and right against it will be the day of the month when the Star *rises Heliacally*. To find the *Heliacal setting*, bring the Star to the West side of the horizon, and turn the quadrant about to the Eastern side, till the 12th degree of it above the horizon cuts the ecliptic; then that degree of the ecliptic which is opposite to this point, is the Sun's place when the Star *sets Heliacally*.

Thus you will find that *Arcturius* rises Heliacally the 6th of *October*, and sets Heliacally *December* the 2d.

PROB. XLV. *To find the place of any Planet upon the globe; and so by that means, to find its place in the Heavens: Also to find at what Hour any Planet will rise or set, or be on the meridian on any Day in the Year.*

You must first seek in an Ephemeris (*White's* Ephemeris will do well enough) for the longitude and latitude of the Planet proposed on that day; mark that point by sticking a little black patch

patch on it; and then for that night you may perform any problem, as before, by a Fixed Star.

Let it be required to find the situation of *Jupiter* among the Fixed Stars in the heavens, and also what time he rises and sets, and comes to the meridian on the 19th of *May*, 1757, N. S. at *London*.

Looking for the 19th of *May*, 1757, in *White's* Ephemeris, I find that *Jupiter's* place at that time is in about 12 degrees of η ; latitude about $1\frac{1}{4}$ degree North. Then looking for that point upon the Celestial globe, I find that α is then nearly in conjunction with the bright Star in the Southern Balance, and about 1 degree North of it.

To find when he rises and sets, and comes to the meridian: Having put a little black patch on the place of *Jupiter*, elevate the globe according to the latitude, and having brought the Sun's place to the meridian, set the hour index to 12 at noon; then turn the mark which was made for *Jupiter*, to the Eastern part of the horizon, I find α will rise about six o'clock in the afternoon; and turning the globe about, I find it comes

to the meridian a little before eleven at night; and sets about half an hour after three the next morning.

This example being understood, it will be easy to find when either of the other two superior Planets, *viz.* *Mars* and *Saturn*, rise, set, and come to the meridian.

I shall conclude this subject about the Globes with the following problems.

PROB. XLVI. *To find all that space upon the Earth, where an Eclipse of one of the Satellites of Jupiter will be visible.*

Having found that place upon the Earth, in which the Sun is vertical at the time of the eclipse, by *Prob.* 13. elevate the globe according to the latitude of the said place; then bring the place to the meridian, and set the hour index to 12 at noon. If *Jupiter* be in consequence of the Sun, draw a line with black lead, or the like, along the Eastern side of the horizon, which line will pass over all those places where the Sun is setting at that time; then count the difference betwixt the right ascension of the Sun, and that of *Jupiter*, and turn the globe Westward, till the hour index points to this differ-

difference; then keep the globe from turning round its axis, and elevate the meridian according to the declination of *Jupiter*. The globe being in this position, draw a line along the Eastern side of the horizon; then the space between this line, and the line before drawn, will comprehend all those places of the Earth where *Jupiter* will be visible, from the setting of the Sun, to the setting of *Jupiter*.

But if *Jupiter* be in antecedence of the Sun (*i. e.* rises before him) having brought the place where the Sun is vertical, to the zenith, and put the hour index to 12 at noon, draw a line on the Western side of the horizon; then elevate the globe according to the declination of *Jupiter*, and turn it about Eastward, until the index points to so many hours distant from noon, as is the difference of the right ascension of the Sun and *Jupiter*. The globe being in this position, draw a line along the Western side of the horizon; then the space contained between this line, and the other last drawn, will comprehend all those places upon the Earth where the Eclipse is visible, between the rising of the Sun, and that of *Jupiter*.

The DESCRIPTION *of the*
Great ORRERY, *lately made*
by Mr. THOMAS WRIGHT,
 Mathematical Instrument-Ma-
 ker to his late MAJESTY.

THE ORRERY is an Astronomical Machine, made to represent the motions of the Planets. These machines are made of various sizes, some having more Planets than others; but I shall here confine myself to the description of that above-mentioned.

In the Introduction we gave a short account of the *Order, Periods, Distances,* and *Magnitudes* of the *Primary Planets*; and of the *Distances* and *Periodical Revolutions* of the *Secondary Planets* round their respective Primaries. We shall here explain their *Stations, Regradations,*
 N *Eclip-*

*The Description of
Eclipses, Phases, &c.* but first let us take
a general view of the *Orrery*.

The De-
scription
of the Or-
rery.

Vide
*Frontis-
piece.*

The frame which contains the wheel-
work, &c. that regulates the whole *Ma-
chine*, is made of fine ebony, and is near
four feet in diameter; the outside there-
of is adorned with twelve pilasters, cu-
riously wrought and gilt: Between these
pilasters the twelve Signs of the *Zodiac*
are neatly painted, with gilded frames.
Above the frame is a broad ring, sup-
ported with twelve pillars: This ring
represents the *Plane* of the *Ecliptic*, up-
on which there are two scales of de-
grees, and between those the names and
characters of the twelve Signs. Near
the outside is a scale of months and
days, exactly corresponding to the Sun's
place at noon, each day throughout
the year.

Above the ecliptic stands some of the
principal circles of the sphere, according
to their respective situations in the hea-
vens, *viz.* N° 10, are the two *Colures*,
divided into degrees, and half degrees;
N° 11, is one half of the *Equinoctial*
Circle, making an angle with the *eclip-
tic* of $23\frac{1}{2}$ degrees. The *Tropic* of *Can-
cer*, and the *Arctic Circle*, are each fixed
parallel,

parallel, and at their proper distance from the equinoctial. On the Northern half of the ecliptic is a brass semicircle, moveable upon two points fixed in ν and ϵ : This semicircle serves as a moveable horizon, to be put to any degree of latitude upon the North part of the meridian. The whole machine is also so contrived, as to be set to any latitude, without in the least affecting any of the inside motions: For this purpose there are two strong hinges (N^o 13.) fixed to the bottom frame, upon which the instrument moves, and a strong brass arch, having holes at every degree, thro' which a strong pin is to be put, according to the elevation. This arch and the two hinges, support the whole machine, when it is lifted up according to any latitude; and the arch at other times lies conveniently under the bottom frame.

When the machine is set to any latitude (which is easily done by two men, each taking hold of two handles, conveniently fixed for that purpose) set the moveable horizon to the same degree upon the meridian, and you may form an idea of the respective altitude, or depressions of the Planets, above or below

the horizon, according to their respective positions, with regard to the meridian.

Within the ecliptic, and nearly in the same plane with it, stands the Sun, and all the Planets, both Primary and Secondary. The Sun (N° 1.) stands in the middle of the whole system, upon a wire, making an angle with the plane of the ecliptic, of about 82 degrees; which is the inclination of the Sun's axis, to the axis of the ecliptic. Next to the Sun is a small ball (N° 2.) representing *Mercury*: Next to *Mercury* is *Venus* (N° 3.) represented by a larger ball (and both these stand upon wires, so that the balls themselves may be more visibly perceived by the eye. The Earth is represented (N° 4.) by an ivory ball, having some of the principal meridians and parallels, and a little sketch of a map described upon it. The wire which supports the Earth, makes an angle with the plane of the ecliptic $66\frac{1}{2}$ degrees, which is the inclination of the Earth's axis to that of the ecliptic. Near the bottom of the Earth's axis is a Dial Plate (N° 9.) having an index pointing to the hours of the day, as the Earth turns rounds its axis.

Round

Round the Earth is a ring, supported by two small pillars, which ring represents the Orbit of the Moon, and the division upon it answers to the Moon's latitude; the motion of this ring represents the motion of the Moon's Orbit, according to that of the Nodes. Within this ring is the Moon (N^o 5.) having a black cap or case, which by its motion, represents the *Phases* of the Moon according to her age. Without the Orbits of the Earth and Moon is *Mars* (N^o 6.) The next in order to *Mars* is *Jupiter*, and his four Moons (N^o 7.) each of these moons is supported by a crooked wire fixed in a socket, which turns about the pillar that supports *Jupiter*. These satellites may be turned by the hand to any position; and yet when the machine is put in motion, they will all move in their proper times. The outermost of all is *Saturn*, and his five Moons (N^o 8.) These moons are supported and contrived after the same manner with those of *Jupiter*. The whole machine is put into motion by turning a small winch (like the key of a clock, N^o 14.) and all the inside work is so truly wrought, that it requires but very small strength to put the whole in motion.

Above the handle there is a cylindrical pin, which may be drawn a little out, or pushed in, at pleasure: when it is pushed in, all the Planets, both primary and secondary, will move according to their respective periods, by turning the handle: When it is drawn out, the motions of the Satellites of *Jupiter* and *Saturn* will be stopped, while all the rest move without interruption. This is a very good contrivance to preserve the instrument from being clogged by the swift motions of the wheels belonging to the Satellites of *Jupiter* and *Saturn*, when the motions of the rest of the Planets are only considered.

There is also a brass lamp having two convex glasses, to be put in the room of the Sun; and also a smaller Earth and Moon, made somewhat in proportion to their distance from each other, which may be put on at pleasure.

The lamp turns round in the same time with the Earth, and by means of the glasses cast a strong light upon her; and when the smaller Earth and Moon are placed on, it will be easy to shew when either of them may be eclipsed.

Having

Having thus given a brief description of the outward part of this machine, I shall next give an account of the phænomena explained by it, when it is put into motion.

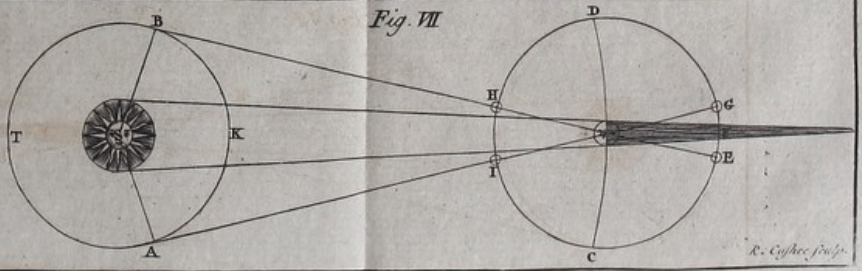
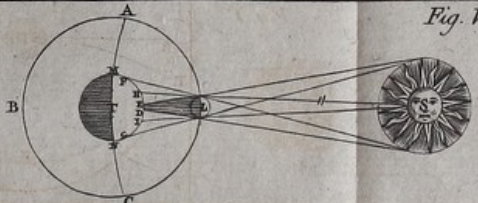
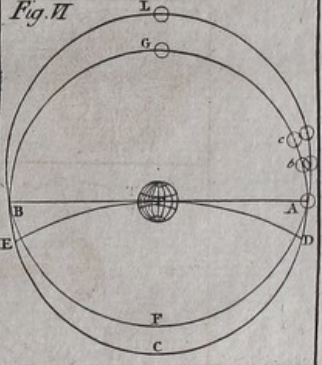
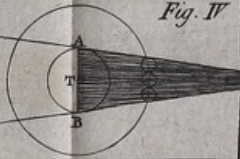
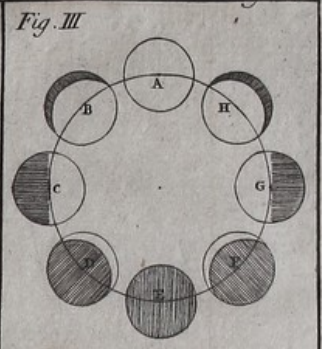
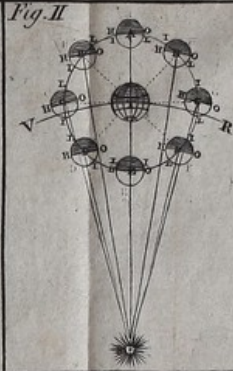
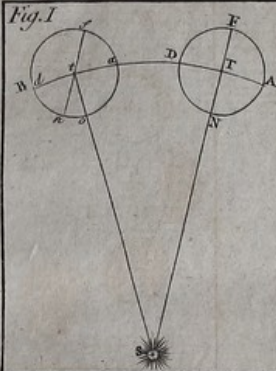
I. *Of the Motions of the Planets in general.*

Having put on the handle, push in the pin which is just above it, and place a small black patch (or bit of wafer) upon the middle of the Sun (for instance) right against the first degree of ϖ ; you may also place patches upon *Venus*, *Mars*, and *Jupiter*, right against some noted point in the ecliptic. If you lay a thread from the Sun to the first degree of ϖ , you may set a mark where it intersects the orbit of each Planet, and that will be a help to note the time of their revolutions.

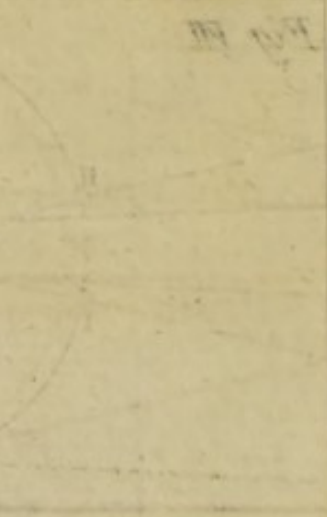
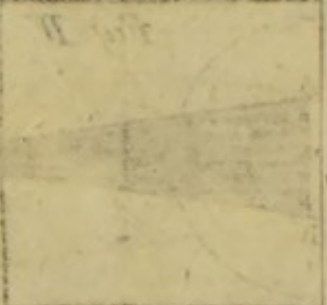
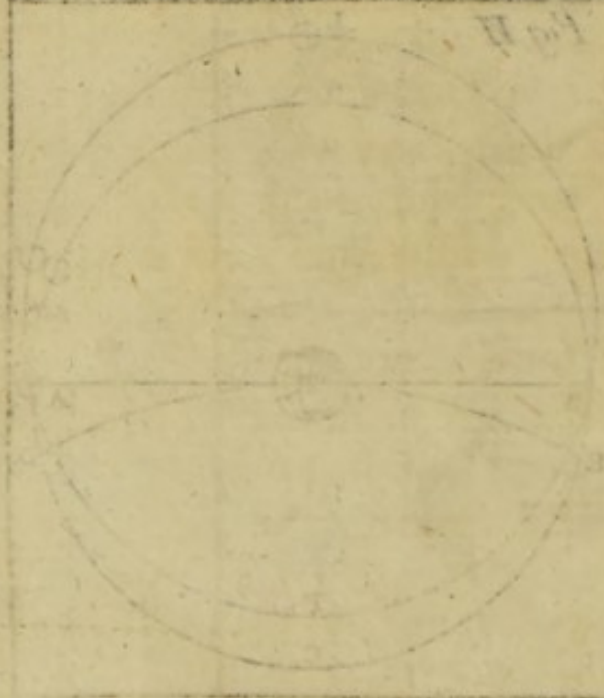
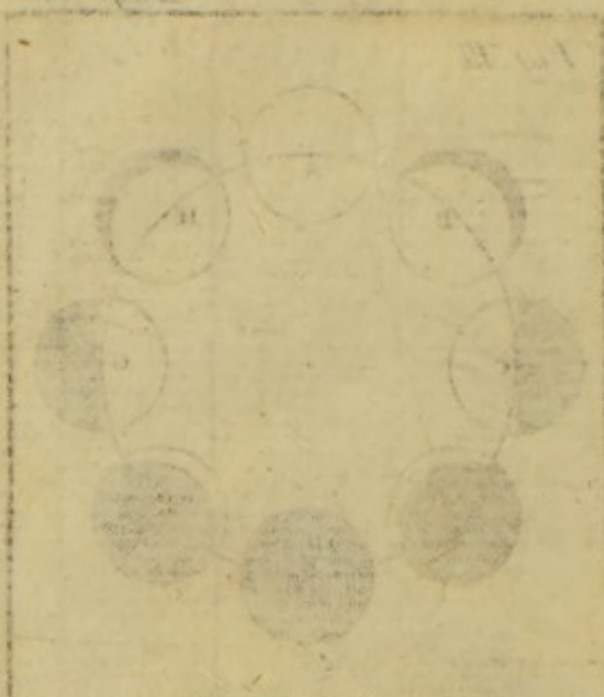
One entire turn of the handle answers to the diurnal motion of the Earth round her axis, as may be seen by the motion of the hour index, which is placed at the foot of the wire on which the terella is fixed. When the index has moved the space of ten hours, you may observe that *Jupiter* has made one

revolution compleat round its axis ; the handle being turned until the hour index has passed over 24 days, 8 hours, will bring the patch upon *Venus* to its former situation with respect to the ecliptic, which shews that ♀ has made one entire revolution round her axis. *Mars* makes one complete revolution round its axis in 24 hours and about 40 minutes. When the handle is turned $25\frac{1}{2}$ times round, the spot upon the Sun will point to the same degree of the ecliptic, as it did when the instrument was first put into motion. By observing the motions of the spots upon the surface of the sun, and of the Planets in the heavens, their diurnal motion was discovered ; after the same manner as we do here observe the motions of their representatives, by that of the marks placed upon them.

If while you turn the handle you observe the Planets, you will see them perform their motions in the same relative times as they really do in the heavens, each making its period in the times mentioned in the Tables, *Page 28*, $27\frac{1}{4}$ turns of the handle will bring the Moon round the earth, which is called a *Periodic Month* ; and all the
while



R. Cyprianus sculp.



while she keeps the same face towards the Earth; for the Moon's annual and diurnal motion are performed both in the same time nearly, so that we always see the same face or side of the Moon.

If before the instrument is put into motion, the satellites of *Jupiter* and *Saturn* be brought into the same right line from their respective primaries, you will see them, as you turn the handle, immediately dispersed from one another, according to their different celerities. Thus one turn of the handle will bring the first of *Jupiter's* Moons about $\frac{2}{7}$ part round *Jupiter* while the second has described but $\frac{2}{7}$ part, the third but above $\frac{1}{7}$, and the fourth not quite $\frac{1}{7}$ part, each of its respective orbits. If you turn the handle until the hour index has moved $18\frac{1}{2}$ hours more, the first satellite will then be brought into its former position, and so has made one entire revolution; the second at the same time will be almost diametrically opposite to the first, and so has made a little more than half of one revolution; the others will be in different aspects, according to the length of their periods, as will be plainly exhibited by the instru-

strument. The same observations may be made with respect to the satellites of *Saturn*.

The machine is so contrived, that the handle may be turned either way; and, if before you put it into motion, you observe the aspect (or situation with respect to each other) of the Planets, and then turn the handle round any number of times; the same number of revolutions being made backwards, will bring all the Planets to their former situations. I shall next proceed to particulars.

Of the Stations and Retrogradations of the Planets.

The primary Planets, as they all turn round the Sun, at different distances, and in different times, appear to us from the Earth to have different motions; as sometimes they appear to move from West to East, according to the order of the signs, which is called their *Direct Motion*; then by degrees they slacken their pace, until at last they lose all their motion, and become *Stationary*, or not to move at all; that is, they appear in the same place with respect to
the

the fixed Stars for some time together; after which they again begin to move, but with a contrary direction, as from East to West, which is called their *Retrograde Motion*; then again they become stationary, and afterwards resume their direct motion. The reason of all these appearances is very evidently shewn by the *Orrery*.

*Retro-
grade Mo-
tion of the
Planets.*

Of the Stations, &c. of the Inferior Planets.

We shall instance in the Planet *Mercury*, because his motion round the Sun differs more from the Earth's than that of *Venus* does.

When *Mercury* is in his superior conjunction (or when he is in a direct line from the Earth beyond the Sun) fasten a string about the axis of the Earth, and extend it over *Mercury* to the ecliptic; then turning the handle, keep the thread all the while extended over \odot , and you will find it move with a direct motion in the ecliptic, but continually slower, until *Mercury* has the greatest elongation from the Earth. Near this position, the thread for some time will lay over *Mercury* without being moved
in

in the ecliptic, tho' the Earth and *Mercury* both continue their progressive motion in their respective orbits. When *Mercury* has got a little past this place, you will find the thread must be moved backward in the ecliptic, beginning first with a slow motion, and then faster by degrees, until *Mercury* is in his inferior conjunction, or directly between the Earth and the Sun. Next this position of φ , his retrograde motion will be the swiftest; but he still moves the same way, tho' continually slower, till he has again come to his greatest elongation, where he will appear the second time to be stationary; after which he begins to move forward, and that faster by degrees, until he is come to the same position with respect to the Earth, that he was in at first. The same observation may be made relating to the motions of *Venus*. In like manner the different motions observed in the superior Planets may be also explained by the *Orrery*. If you extend the thread over *Jupiter*, and proceed after the same manner as before we did in regard to *Mercury*, you will find that from the time *Jupiter* is in conjunction with the Sun, his motion is direct; but continually slower, until the Earth is nearly in a qua-

quadrate aspect with *Jupiter*, near which position *Jupiter* seems to be stationary: After which he begins to move, and continually mends his pace, until he comes in opposition to the Sun, at which time his retrograde motion is swiftest. He still seems to go backward, but with a slower pace, till the Earth and he are again in a quadrate aspect, where *Jupiter* seems to have lost all his motion; after which he again resumes his direct motion, and so proceeds faster by degrees, till the Earth and he are again in opposition to each other.

These different motions observed in the Planets, are easily illustrated, as followeth: The lesser circle round the Sun is the orbit of *Mercury*, in which he performs his revolution round the Sun, in about three months, or while the Earth is going thro' $\frac{1}{4}$ part of her orbit, or from A to N. The numbers 1, 2, 3, &c. in the orbit of *Mercury*, show the spaces he describes in a week nearly, and the distance AB, BC, CD, &c. in the Earth's orbit, do likewise show her motion in the same time. The letters A, B, C, &c. in the great orb, are the motions of *Mercury* in the Heavens, as they appear from the Earth.

Now

Plate 3.
Fig. 1.

Now if the Earth be supposed in A, and *Mercury* in 12, near his superior conjunction with the Sun, a spectator on the Earth will see $\text{\textcircled{z}}$ as if he were in the point of the Heavens A, and while $\text{\textcircled{z}}$ is moving from 12 to 1, and from 1 to 2, &c. the Earth in the same time also moves from A to B, and from B to C, &c. All which time $\text{\textcircled{z}}$ appears in the Heavens to move in a direct motion from A to B, and from B to C, &c. but gradually slower, until he arrives near the point G; near this place he appears stationary, or to stand still; and afterwards (though he still continues to move uniformly in his own orbit, with a progressive motion) yet in the sphere of the fixed Stars he will appear to be retrograde, or to go backwards, as from G to H, from H to I, &c. until he has arrived near the point L, where again he will appear to be stationary; and afterwards to move in a direct motion from L to M, and from M to N, &c.

What has here been shewed concerning the motions of *Mercury*, is also to be understood of the motions of *Venus*; but the conjunctions of *Venus* with the Sun do not happen so often as in *Mercury*; for *Venus* moving in a larger orbit,
and

and much slower than *Mercury*, does not so often overtake the Earth. But the retrogradations are much greater in *Venus* than they are in *Mercury*, for the same reasons.

The innermost circle represents the *Fig. 2.* Earth's orbit, divided into 12 parts, answering to her monthly motion; the greater circle is the orbit of *Jupiter*, which he describes in about 12 years; and therefore the $\frac{1}{12}$ thereof, from A to N, defines his motion in one of our years nearly; and the intermediate divisions, A, B, C, &c. his monthly motion. Let us suppose the Earth to be in the point of her orbit 12, and *Jupiter* in A, in his conjunction with the Sun; it is evident that from the Earth *Jupiter* will be seen in the great orb, or in the point of the Heavens A, and while the Earth is moving from 12 to 1, 2, &c. μ also moves from A to B, &c. all which time he appears in the Heavens to move with a direct motion from A to B, C, &c. until he comes in opposition to the Earth near the point of the Heavens E, where he appears to be stationary; after which μ again begins to move (though at first with a slow pace) from E through F, G, H, I, to K, where

where again he appears to stand still, but afterwards he reassumes his direct motion from I through K, to M, &c.

From the construction of the preceding figure it appears, that when the superior Planets are in conjunction with the Sun, their direct motion is much quicker than at other times; and that because they really move from West to East, while the Earth in the opposite part of the Heavens is carried the same way, and round the same center. This motion afterwards continually slackens, until the Planet comes almost in opposition to the Sun, when the line joining the Earth and Planet, will continue for some time nearly parallel to itself, and so the Planet seems from the Earth to stand still; after which, it begins to move with a slow motion backward, until it comes into a quartile aspect with the Sun, when again it will appear to be stationary, for the above reasons; after that it will resume its direct motion, until it comes into a conjunction with the Sun, then it will proceed as above explained. Hence it also appears, that the retrogradations of the superior Planets are much slower than their direct motions, and their continuance

nuance much shorter; for the Planet, from its last quarter, until it comes in opposition to the Sun, appears to move the same way with the Earth, by whom it is then overtaken: After which it begins to go backwards, but with a slow motion, because the Earth being in the same part of the Heavens, and moving the same way that the Planet really does, the apparent motion of the Planet backwards must thereby be lessened.

What has been here said concerning the motions of *Jupiter*, is also to be understood of *Mars* and *Saturn*. But the retrogradations of *Saturn* do oftener happen than those of *Jupiter*, because the Earth oftener overtakes *Saturn*; and for the same reason, the regressions of *Jupiter* do oftener happen than those of *Mars*. But the retrogradations of *Mars* are much greater than those of *Jupiter*, whose are also much greater than those of *Saturn*.

In either of the satellites of *Jupiter* or *Saturn*, these different appearances in the neighbouring Worlds are much oftener seen than they are by us in the primary Planets.

We never observe these different motions in the Moon, because she turns round the Earth as her center; neither do we observe them in the Sun, because he is the center of the Earth's motion; whence the apparent motion of the Sun always appears the same way round the Earth.

Of the Annual and Diurnal Motion of the Earth, and of the increase and decrease of Days and Nights.

The Earth in her annual motion round the Sun, has her axis always in the same direction, or parallel to itself; that is, if a line be drawn parallel to the axis, while the Earth is in any point of her orbit, the axis in all other positions of the Earth will be parallel to the said line. This parallelism of the axis, and the simple motion of the Earth in the ecliptic, solves all the phænomena of different seasons. These things are very well illustrated by the *Orrery*.

If you put on the lamp in the place of the Sun, you will see how one half of our globe is always illuminated by the Sun, while the other hemisphere remains in darkness; how Day and Night
are

are formed by the revolution of the Earth round her axis; for as she turns from West to East, the Sun appears to move from East to West. And while the Earth turns in her orbit, you may observe that her axis always points the same way, and the several seasons of the year continually change.

To make these things plainer, we will take a view of the Earth in different parts of her orbit.

When the Earth is in the first point of *Libra* (which is found by extending a thread from the Sun, and over the Earth, to the ecliptic) we have the *Vernal Equinox*, and the Sun at that time appears in the first point of γ . In this position of the Earth, two Poles of the world are in the lines separating light and darkness; and as the Earth turns round her axis, just one half of the equator, and all its parallels, will be in the light, and the other half in the dark; and therefore the days and nights must be every where equal.

As the Earth moves along in her orbit, you will perceive the North Pole advances by degrees into the illuminated

hemisphere, and at the same time the South Pole recedes into darknes; and in all places to the Northward of the equator, the days continually lengthen, while the contrary happens in the Southern parts, until at length the Earth is arrived in *Capricorn*. In this position of the Earth all the space included within the arctic circle falls wholly within the light, and all the opposite part lying within the antarctic circle, is quite involved in darknes. In all places between the equator and the arctic circle, the days are now at the longest, and are gradually longer, as the places are more remote from the equator. In the Southern hemisphere there is a contrary effect. All the while the Earth is travelling from *Capricorn* towards *Aries*, the North Pole gradually recedes from the light, and the South Pole approaches nearer to it; the days in the Northern hemisphere gradually decrease, and in the Southern hemisphere they increase in the same proportion, until the Earth be arrived in ϵ ; then the two Poles of the world lie exactly in the line separating light and darknes; and the days are equal to the nights in all places of the world. As the Earth advances towards *Cancer*, the North Pole gradually recedes from the light,

light, while the Southern one advances into it, at the same rate. In the Northern hemisphere the days decrease, and in the Southern one they gradually lengthen, until the Earth being arrived in *Cancer*, the North frigid Zone is all involved in darkness, and the South frigid Zone falls intirely within the light ; the days every where in the Northern hemisphere are now at the shortest, and to the Southward they are at the longest. As the Earth moves from hence towards *Libra*, the North Pole gradually approaches the light, and the other recedes from it ; and in all places to the Northward of the equator, the days now lengthen, while in the opposite hemisphere they gradually shorten, until the Earth has gotten into \sphericalangle ; in which position the days and nights will again be of equal length in all parts of the world.

You might have observed, that in all positions of the Earth, one half of the equator was in the light, and the other half in darkness ; whence under the equator, the days and nights are always of the same length : And all the while the Earth was going from \sphericalangle towards \sphericalcap , the North Pole was constantly illuminated, and the South Pole all the

while in darkness; and for the other half year the contrary. Sometimes there is a semicircle exactly facing the Sun, fixed over the middle of the Earth, which may be called the horizon of the disk: This will do instead of the lamp, if that half of the Earth which is next the Sun be considered, as being the illuminated hemisphere, and the other half, to be that which lies in darkness.

Plate 4.

The great circle ν , δ , π , $\&c.$ represent the Earth's annual orbit; and the four lesser circles $ESQC$, the ecliptic, upon the surface of the Earth, coinciding with the great ecliptic in the Heavens. These four lesser figures represent the Earth in the four cardinal points of the ecliptic, P being the North Pole of the equator, and p the North Pole of the ecliptic; SPC , the solstitial colure which is always parallel to the great solstitial colure σ \circ ω in the Heavens; EPQ the equinoctial colure. The other circles passing thro' P , are meridians at two hours distance from one another; the semicircle $E\AE Q$ is the Northern half of the equator; the parallel circle touching the ecliptic in S , is the tropic of *Cancer*; the dotted circle, the parallel of *London*, and the small circle,

cle, touching the Pole of the ecliptic, is the *Arctic Circle*. The shaded part, which is always opposite to the Sun, is the obscure hemisphere, or that which lies in darkness; and that which is next the Sun, is the illuminated hemisphere.

If we suppose the Earth in α , she will then see the Sun in γ (which makes our vernal equinox) and in this position the circle bounding light and darkness, which here is SC, passes thro' the poles of the World, and bisects all the parallels of the equator; and therefore the diurnal and nocturnal arches, or the length of the days and nights, are equal in all places of the world.

But while the Earth in her annual course, moves through m , \dagger , to ν , the line SC, keeping still parallel to itself, or to the place where it was at first, the Pole P will, by this motion, gradually advance into the illuminated hemisphere; and also the diurnal arches of the parallels gradually increase, and consequently the nocturnal ones decrease in the same proportion, until the Earth has arrived into ν ; in which position the Pole P, and all the space within the

arctic circle, fall wholly within the illuminated hemisphere, and the diurnal arches of all the parallels that are without this circle, will exceed the nocturnal arches more or less, as the places are nearer to, or farther off from it, until the distance from the Pole is as far as the equator, where both these arches are always equal.

Again, while the Earth is moving from ν thro' μ , λ , to κ , the Pole P begins to incline to the line, distinguishing light and darkness, in the same proportion that before it receded from it; and consequently the diurnal arches gradually lessen, until the Earth has arrived into κ , where the Pole P will again fall on the horizon, and so cause the days and nights to be every where equal. But when the Earth has passed κ , while she is going thro' δ and π , &c. the Pole P will begin to fall in the obscure hemisphere, and so recede gradually from the light, until the Earth is arrived in ϖ ; in which position not only the Pole, but all the space within the arctic circle, are involved in darkness, and the diurnal arches of all the parallels, without the arctic circle, are equal to the nocturnal arches of the
same

same parallels, when the Earth was in the opposite point ν ; and it is evident that the days are now at the shortest, and the nights the longest. But when the Earth has past this point, while she is going through ω and μ , the Pole P will again gradually approach the light, and so the diurnal arches of the parallels gradually lengthen, until the Earth is arrived in ϵ ; at which time the days and nights will again be equal in all places of the World, and the Pole itself just see the Sun.

Here we only considered the phænomena belonging to the Northern parallels; but if the Pole P be made the South Pole, then all the parallels of latitude will be parallels of South latitude, and the days, every where, in any position of the Earth, will be equal to the nights of those who lived in the opposite hemisphere, under the same parallels.

Of the Phases of the Moon, and of her Motion in her Orbit.

The orbit of the Moon makes an angle with the plane of the ecliptic, of above $5\frac{1}{4}$ degrees, and cuts it in two points, diametrically opposite (after the
same

Nodes. same manner as the equator and the ecliptic cut each other upon the globe, in ν and ϖ) which points are called the *Nodes*; and a right line joining these points, and passing through the center of the Earth, is called the *Line of the Nodes*. That node where the Moon begins to ascend Northward above the plane of the ecliptic, is called the *Ascending Node*, and the *Head of the Dragon*, and is thus commonly marked α . The other node, from whence the Moon descends to the Southward of the ecliptic, is called the *Descending Node*, and the *Dragon's Tail*, and is thus marked γ . The line of nodes continually shifts itself from East to West, contrary to the order of the signs; and with this *retrograde* motion, makes one revolution round the Earth, in the space of about 19 years.

Dragon's Head.

Dragon's Tail.

Retrograde Motion of the Nodes.

The Moon describes its orbit round the Earth in the space of 27 days and 7 hours, which space of time is called a *Periodical Month*; yet from one conjunction to the next, the Moon spends 29 days and a half, which is called a *Synodical Month*; because while the Moon in her proper *Orbit* finishes her course, the Earth advances near a whole sign

in the ecliptic; which space the Moon has still to describe, before she will be seen in conjunction with the Sun.

When the Moon is in conjunction with the Sun, note her place in the ecliptic; then turning the handle, you will find that 27 days and 7 hours will bring the Moon to the same place; and after you have made $2\frac{1}{4}$ revolutions more, the Moon will be exactly betwixt the Sun and the Earth.

The Moon all the while keeps in her orbit, and so the wire that supports her continually rises or falls in a socket, as she changes her latitude; the black cap shifts itself, and so shews the phases of the Moon, according to her age, or how much of her enlightened part is seen from the Earth. In one synodical month, the line of the nodes moves about $1\frac{1}{2}$ degree from West to East, and so makes one entire revolution in 19 years.

Let AB be an arch of the Earth's orbit, and when the Earth is in T, let the Moon be in N, in conjunction with the Sun in S, while the Moon is describing her orbit NAFD, the Earth will describe

*Phases of
the Moon.*

*Plate V.
Fig. 4.*

scribe the arch of her orbit Tt ; and when the Earth has got into the point t , the Moon will be in the point of her orbit n , having made one compleat revolution round the Earth. But the Moon, before she comes in conjunction with the Sun, must again describe the arch no ; which arch is similar to Tt , because the lines FN , fn , are parallel; and because, while the Moon describes the arch no , the Earth advances forward in the ecliptic; the arch described by the Moon, after she has finished her periodical month, before she makes a synodical month, must be somewhat greater than no . To determine the mean length of a synodical month, find the diurnal motion of the Moon (or the space she describes round the Earth in one day) and likewise the diurnal motion of the Earth; then the difference betwixt the two motions, is the apparent motion of the Moon round the Earth in one day; then it will be, as this differential arch is to a whole circle; so is one day to that space of time wherein the Moon appears to describe a compleat circle round the Earth, which is about $29\frac{1}{2}$ days. But this is not always a true *Lunation*, for the motion of the Moon is sometimes faster, and sometimes slower,

er, according to the position of the Earth in her orbit.

In one synodical month the Moon has all manner of aspects with the Sun and Earth, and because she is opaque, that face of her's will only appear bright which is towards the Sun, while the opposite remains in darkness. But the inhabitants of the earth can only see that face of the Moon which is turned towards the Earth; and therefore, according to the various positions of the Moon, in respect of the Sun and Earth, we observe different portions of her illuminated face, and so a continual change in her * *Phases*.

Let S be the Sun, R T V an arch of *Fig. 2.* the Earth's orbit, T the Earth, and the circle ABCD, &c. the Moon's orbit, in which she turns round the Earth in the space of a month; and let A, B, C, &c. be the centers of the Moon in different parts of her orbit.

Now if with the lines S A, S B, &c. we join the centers of the Sun and
Moon,

* *Phases* of the Moon are those different appearances we observe in her, according to her position in respect to the Sun and Earth.

Moon, and at right angles to these draw the lines HO ; the said lines HO will be the circles that separate the illuminated part of the Moon from the dark and obscure. Again, if we conceive another line IL to be drawn at right angles to the lines TA , TB , &c. passing from the center of the Earth to the Moon, the said Line IL will divide the visible hemisphere of the Moon, or that which is turned towards us, from the invisible, or that which is turned from us; and this circle may be called the *Circle of Vision*.

Now it is manifest, that whenever the Moon is in the position A , or in that point of her orbit which is opposite to the Sun, the circle of vision, and the circle bounding light and darkness, do coincide, and all the illuminated face of the Moon is turned towards the Earth, and is visible to us; and in this position *Full Moon.* the *Moon* is said to be *full*. But when the Moon arrives to B , all her illuminated face is then not towards the Earth, there being a part of it, HBI , not to be seen by us; and then her visible face is deficient from a circle, and appears of a gibbous form, as in B , *Fig. 3*. Again when she arrives to C , the two foremen-

mentioned circles cut each other at right angles, and then we observe a *half Moon*, Half Moon. as in C, *Fig. 3.* And again the illuminated face of the Moon is more and more turned from the Earth, until she comes to the Point E, where the circle of vision, and that bounding light and darkness, do again coincide. Here the Moon disappears, the illuminated part being wholly turned from the Earth; and she is now said to be in *Conjunction* with the *Sun*, because she is in the same direction from the Earth that the Sun is in, which position we call a *New Moon*. New Moon. When the Moon is arrived to F, she again assumes a horned figure, but her horns (which before the change were turned Westward) have now changed their position, and look Eastward. When she has arrived to a quadrate aspect at G, she will appear bisected, like a half Moon, afterwards she will still grow bigger, until at last she comes to A, where again she will appear in her full splendor.

The same appearances which we observe in the Moon are likewise observed by the *Lunarians* in the Earth, our Earth being a Moon to them, as their Moon is to us; and we are observed by them to be carried round in the space of time
that

that they are really carried round the Earth. But the same phases of the Earth and Moon happen when they are in contrary position; for when the Moon is in conjunction to us, the Earth is then in opposition to the Moon, and the *Lunarians* have then a full Earth, as we in a similar position have a full Moon. When the Moon comes in opposition to the Sun, the Earth, seen from the Moon, will appear in conjunction with her, and in that position the Earth will disappear; afterwards she will assume a horned figure, and so shew the same phases to the inhabitants of the Moon as she does to us.

Of the Eclipses of the Sun and Moon.

Eclipse. An *Eclipse* is that deprivation of light in a Planet, when another is interposed betwixt it and the Sun. Thus, an eclipse of the Sun is made by the interposition of the Moon at her conjunction, and an eclipse of the Moon is occasioned by the shadow of the Earth falling upon the Moon, when she is in opposition to the Sun.

Fig. 4. Let S be the Sun, T the Earth, and ABC its shadow; now if the Moon, when

when she is in opposition to the Sun, should come into the conical space ABC, she will then be deprived of the solar light, and so undergo an eclipse. *Lunar Eclipse.*

In the same manner, when the shadow of the Moon falls upon the Earth (which can never happen but when the Moon is in conjunction with the Sun) that part upon which the shadow falls will be involved in darkness, and the Sun eclipsed. But because the Moon is much less than the Earth, the shadow of the ☾ cannot cover the whole Earth, but only a part of it. Let S be the Sun, T the Earth, A B C the Moon's orbit, and L the Moon in conjunction with the Sun: Here the shadow of the Moon falls only upon the part D E of the Earth's surface, and there only the Sun is intirely hid: but there are other parts E F, D G, on each side of the shadow, where the inhabitants are deprived of part of the Solar rays, and that more or less, according to their distance from the shadow. Those who live at H and I will see half of the Sun eclipsed, but in the spaces F M, G N, all the Sun's body will be visible, without any eclipse. From the preceding figure it appears, that an eclipse of the Sun does not reach

The Description of

a great way upon the superficies of the Earth; but the whole body of the Moon may sometimes be involved in the Earth's shadow.

Fig. 6.

Although the Moon seen from the Earth, and the Earth seen from the Moon, are each alternately, once a month, in conjunction with the Sun; yet, by reason of the inclination of the Moon's orbit to the ecliptic, the Sun is not eclipsed every new Moon, nor the Moon at every full. Let *T* be the Earth, *DTE* an arch of the ecliptic, *ALBF*, the Moon's orbit, having the Earth *T*, in its center; and let *AGBC* be another circle coinciding with the ecliptic, and *A*, *B*, the nodes, or the two points where the Moon's orbit and the ecliptic cut each other. *A* the ascending node, and *B* the descending node. The angle *GAL* equal to *GBL* is the inclination of the Moon's orbit to the ecliptic, being about $5\frac{1}{4}$ degrees. Now a spectator from the Earth at *T*, will observe the Sun to move in the circle *AGBC*, and the Moon in her orbit *ALBF*; whence it is evident, that the Sun and Moon can never be seen in a direct line from the center of the Earth, but when the Moon is in one of the nodes *A* or *B*;
and

and then only will the Sun appear centrally eclipsed. But if the conjunction of the Moon happens when she is any where within the distance $A c$ of the nodes, either North or South, the Sun will then be eclipsed, more or less, according to the distance from the node A , or B . If the conjunction happens when the Moon is in b , the Sun will be then one half eclipsed; and if it happens when she is in c , the Moon's limb will just touch the Sun's disk, without hiding any part of it.

The shadow of the Earth at the place where the Moon's orbit intersects it, is three times as large as the Moon's diameter, as in *Fig. 4.* and therefore it often happens that eclipses of the Moon are total, when they are not central: And for the same reason the Moon may sometimes be totally eclipsed for three hours together; whereas total eclipses of the Sun can scarcely ever exceed four minutes.

The eclipses of the Sun and Moon are very well explained by the *Orrery*: Thus having put the lamp in the place of the Sun, and the little Earth and the little Moon in their proper places, in-

The Description of

stead of the larger ones, let the room, wherein the instrument stands, be darkened; then turning the handle about, you will see when the conjunction of the Moon happens. When she is in, or near one of the nodes, her shadow will fall upon the Earth, and so deprive that part upon which it falls of the light of the Sun: If the conjunction happens when the Moon is not near one of the nodes, the light of the lamp will fall upon the Earth, either above or below the Moon, according to her latitude at that time. In like manner, when the full Moon happens near one of the nodes, the shadow of the Earth will fall upon the Moon; and if the Moon's latitude be but small, her whole face will be involved in darkness. At other times, when the full Moon happens when she is not near one of her nodes, the shadow of the Earth will pass either above or below the Moon, and so by that means the Moon will escape being eclipsed.

Of the Eclipses of the Satellites of Jupiter.

The apparent diameters of the inferior Planets are so small, that when they pass betwixt us and the Sun, they only
appear

appear like small spots upon the Sun's surface, without depriving us of any sensible quality of his light. The shadow of the Earth likewise terminates before it reaches any of the superior Planets, so that they are never eclipsed by us; and the Earth, when she is in conjunction with the Sun, only appears like a black spot upon his surface.

But *Jupiter* and his Moons mutually eclipse each other, as our Earth and Moon do; as also doth *Saturn* and his Moons. The satellites of *Jupiter* become twice hid from us, in one circulation round μ ; viz. once behind the body of *Jupiter*, i. e. when they are in the right line joining the centers of the Earth and μ ; and again they become invisible when they enter the shadow of *Jupiter*, which happens when they are at their Full, as seen from μ , at which times they also suffer eclipses; which eclipses happen to them after the same manner as they do to our Moon, by the interposition of the Earth betwixt her and the Sun.

Let S be the Sun, ABT the Earth's *Fig. 7.*
orbit; and C μ D, an arch of *Jupiter's*
orbit, in which let *Jupiter* be in the
P 3 point

The Description of

point μ ; and let CFDH be the orbit of one of *Jupiter's* satellites, which we will here suppose to be the farthest from him. These satellites, while they move through the inferior parts of their orbs, *viz.* from D thro' H, I, to C, seem from the Earth and the Sun to have a retrograde motion; but when they are in the superior part of their orbit, they are then seen to move from West to East, according to their true motion. Now while they describe the superior part of their orbits, they will be twice hid from the Earth, once in the shadow of μ , and once behind his body. If *Jupiter* be more Westerly than the Sun, that is, when the Earth is in A, they will be first hid in the shadow F, and afterwards behind the body of μ in G: But when the Earth is in B, then they are first hid behind μ 's body in E, and afterwards fall into the shadow F. While the satellites describe the inferior parts of their orbit, they only once disappear, which may be either in I or H, according to the position of the Earth, in which places they cannot be distinguished from the body of *Jupiter*.

When the satellites seen from μ are in conjunction with the Sun, their shadows

dows will then fall upon α , and some part of his body be involved in darkness, to which part the Sun will be totally eclipsed.

By observing the eclipses of *Jupiter's* satellites, it was first discovered that light is not propagated instantaneously, though it moves with an incredible swiftness: For if light came to us in an instant, an observer in T will see an eclipse of one of the satellites, at the same time that another in K would. But it has been found by observations, that when the Earth is in K, at her nearest distance from *Jupiter*, these eclipses happen much sooner than when she is in T. Now having the difference of time betwixt these appearances in K and T, we may find the length of time the light takes in passing from K to T, which space is equal to the diameter of the Earth's annual orb. By these kinds of observations it has been found, that light reaches from the Sun to us in the space of eleven minutes of time, which is at least at the rate of 100,000 miles in a second.

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