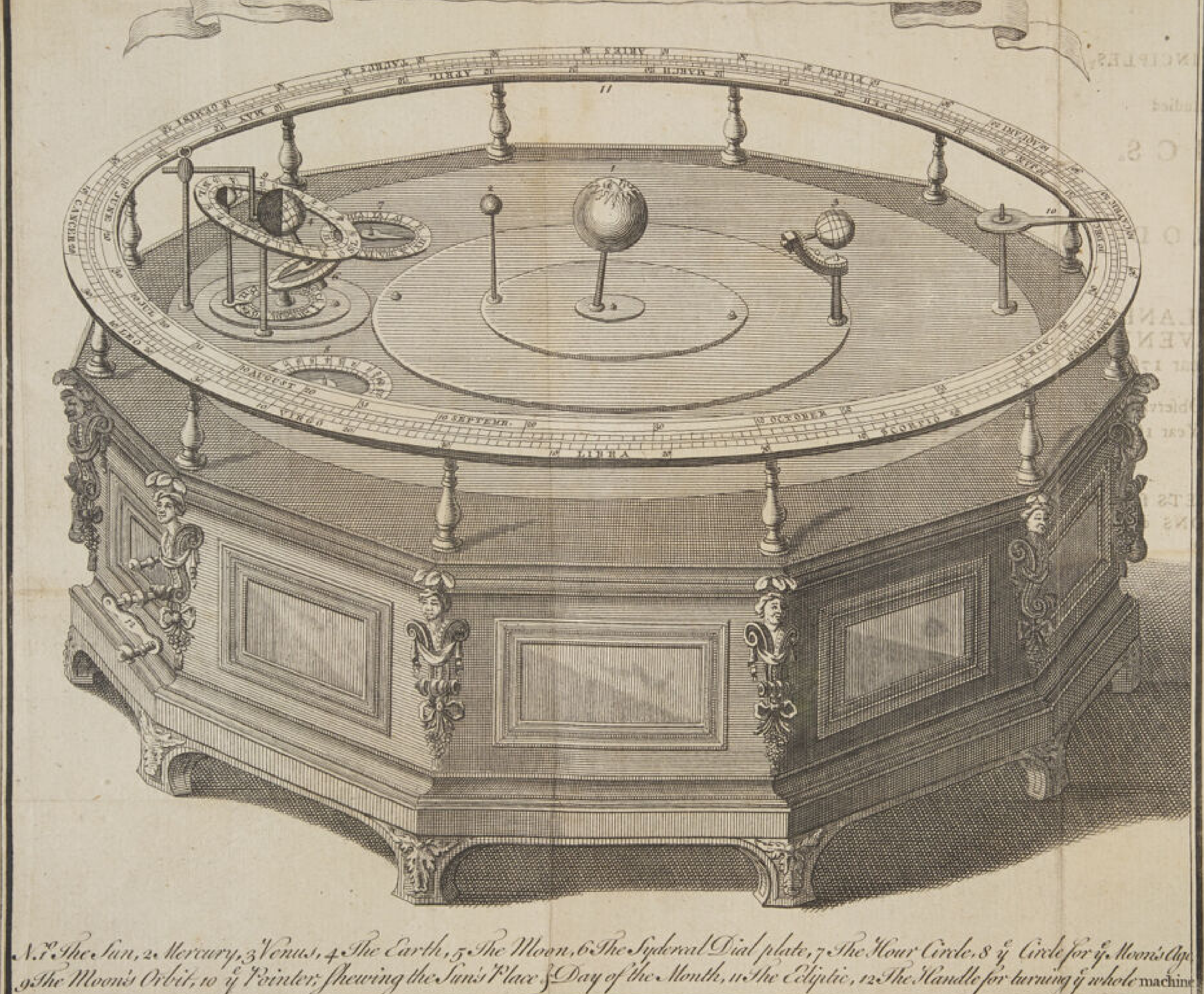
Astronomy explained upon Sir Isaac Newton's principles. And made easy to those who have not studied mathematics / To which are added, a plain method of finding the distances of all the planets from the sun, by the transit of Venus over the sun's disc, in the year 1761. An account of Mr. Horrox's observation of the transit of Venus in the year 1639; and, of the distances of all the planets from the sun, as deduced from observations of the transit in the year 1761. By James Ferguson.

Mary Payne junior —

bought of Mr. Cadell in the year

1771

The ORRERY, made by *JAMES FERGUSON.*



N.º 1 The Sun, 2 Mercury, 3 Venus, 4 The Earth, 5 The Moon, 6 The Sydereal Dial plate, 7 The Hour Circle, 8 ye Circle for ye Moon's Age, 9 The Moon's Orbit, 10 ye Pointer, shewing the Sun's Place & Day of the Month, 11 The Ecliptic, 12 The Handle for turning ye whole machine.

J. Ferguson inv. et deline. — *G. Child Sculp.*

ASTRONOMY

EXPLAINED UPON

Sir ISAAC NEWTON's PRINCIPLES,

And made eaſy to thoſe who have not ſtudied

MATHEMATICS.

To which are added,

A PLAIN METHOD

OF FINDING

The DISTANCES of all the PLANETS from the SUN, by the TRANSIT of VENUS over the SUN's DISC, in the Year 1761.

An Account of Mr. HORROX's Obſervation of the TRANSIT of VENUS in the Year 1639:

AND,

Of the DISTANCES of all the PLANETS from the SUN, as deduced from OBSERVATIONS of the TRANSIT in the Year 1761.

By JAMES FERGUSON, *F.R.S.*

HEB. xi. 3. *The Worlds were framed by the Word of* GOD.
JOB xxvi. 7. *He hangeth the Earth upon nothing.*
——— 13. *By his Spirit he hath garniſhed the Heavens.*

THE FOURTH EDITION, correcred.

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MDCCLXX.

1770

TO

THE RIGHT HONOURABLE

GEORGE EARL OF MACCLESFIELD,

VISCOUNT PARKER of EWELME in OXFORDSHIRE,

AND

BARON of MACCLESFIELD in CHESHIRE;

PRESIDENT of the ROYAL SOCIETY of LONDON,

MEMBER of the ROYAL ACADEMY OF SCIENCES at PARIS,

OF THE

IMPERIAL ACADEMY OF SCIENCES at PETERSBURG,

AND ONE OF THE

TRUSTEES OF THE BRITISH MUSEUM;

DISTINGUISHED

By his GENEROUS ZEAL for promoting every

BRANCH of USEFUL KNOWLEDGE;

THIS

TREATISE OF ASTRONOMY

IS INSCRIBED,

With the MOST PROFOUND RESPECT,

By HIS LORDSHIP's

MOST OBLIGED,

AND

MOST HUMBLE SERVANT,

JAMES FERGUSON.

THE

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CONTENTS.

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ASTRONOMY

EXPLAINED UPON

Sir ISAAC NEWTON's PRINCIPLES.

CHAP. I.

Of Aſtronomy in general.

1. OF all the ſciences cultivated by mankind, Aſtronomy is acknowledged to be, and undoubtedly is, the moſt ſublime, the moſt intereſting, and the moſt uſeful. For, by knowledge derived from this ſcience, not only the bulk of the Earth is diſcovered, the ſituation and extent of the countries and kingdoms upon it aſcertained, trade and commerce carried on to the remoteſt parts of the world, and the various products of ſeveral countries diſtributed for the health, comfort, and conveniency of it's inhabitants; but our very faculties are enlarged with the grandeur of the ideas it conveys, our minds exalted above the low contracted prejudices of the vulgar, and our underſtandings clearly convinced, and affected with the conviction of the exiſtence, wiſdom, power, goodneſs, immutability, and ſuperintendency of the SUPREME BEING! So that without an hyperbole, *The general uſe of Aſtronomy.*

"*An undevout Aſtronomer is mad**."

2. From this branch of knowledge we alſo learn by what means or laws the Almighty carries on, and continues the admirable harmony, order, and connexion obſervable throughout the planetary ſyſtem; and are led by very powerful arguments to form the pleaſing deduction, that minds capable of

* Dr. YOUNG's Night Thoughts.

ſuch deep reſearches not only derive their origin from that adorable Being, but are alſo incited to aſpire after a more perfect knowledge of his nature, and a ſtricter conformity to his will.

The Earth but a point as ſeen from the Sun.

3. By Aſtronomy we diſcover that the Earth is at ſo great a diſtance from the Sun, that if ſeen from thence it would appear no bigger than a point; although it's circumference is known to be 25,020 miles. Yet that diſtance is ſo ſmall, compared with the Earth's diſtance from the Fixed Stars, that if the orbit in which the Earth moves round the Sun were ſolid, and ſeen from the neareſt Star, it would likewiſe appear no bigger than a point, although it is at leaſt 162 millions of miles in diameter. For the Earth in going round the Sun is 162 millions of miles nearer to ſome of the Stars at one time of the year, than at another; and yet their apparent magnitudes, ſituations, and diſtances from one another ſtill remain the ſame; and a teleſcope which magnifies above 200 times does not ſenſibly magnify them: which proves them to be at leaſt 400 thouſand times farther from us than we are from the Sun.

4. It is not to be imagined that all the Stars are placed in one concave ſurface, ſo as to be equally diſtant from us; but that they are ſcattered at immenſe diſtances from one another through unlimited ſpace. So that there may be as great a diſtance between any two neighbouring Stars, as between our Sun and thoſe which are neareſt to him. Therefore an Obſerver, who is neareſt any fixed Star, will look upon it alone as a real Sun; and conſider the reſt as ſo many ſhining points, placed at equal diſtances from him in the Firmament.

The Stars are Suns,

5. By the help of teleſcopes we diſcover thouſands of Stars which are inviſible to the naked eye; and the better our glaſſes are, ſtill the more become viſible: ſo that we can ſet no limits either to their number or their diſtances. The celebrated HUYGENS carries his thoughts ſo far, as to believe it not

and innumerable.

not impossible that there may be Stars at such inconceivable distances, that their light has not yet reached the Earth since it's creation; although the velocity of light be a million of times greater than the velocity of a cannon-bullet, as shall be demonstrated afterwards, § 197, 216: and, as Mr. ADDISON very justly observes, this thought is far from being extravagant, when we consider that the Universe is the work of infinite power, prompted by infinite goodness; having an infinite space to exert itself in; so that our imaginations can set no bounds to it.

6. The Sun appears very bright and large in comparison of the Fixed Stars, because we keep constantly near the Sun, in comparison of our immense distance from the Stars. For, a spectator, placed as near to any Star as we are to the Sun, would see that Star a body as large and bright as the Sun appears to us: and a spectator, as far distant from the Sun as we are from the Stars, would see the Sun as small as we see a Star, divested of all it's circumvolving Planets; and would reckon it one of the Stars in numbering them. Why the Sun appears bigger than the Stars.

7. The Stars, being at such immense distances from the Sun, cannot possibly receive from him so strong a light as they seem to have; nor any brightness sufficient to make them visible to us. For the Sun's rays must be so scattered and dissipated before they reach such remote objects, that they can never be transmitted back to our eyes, so as to render these objects visible by reflexion. The Stars therefore shine with their own native and unborrowed lustre, as the Sun does; and since each particular Star, as well as the Sun, is confined to a particular portion of space, it is plain that the Stars are of the same nature with the Sun. The Stars are not enlightened by the Sun.

8. It is no ways probable that the Almighty, who always acts with infinite wisdom and does nothing in vain, should create so many glorious Suns, fit for so many important purposes, and place them

at ſuch diſtances from one another, without proper objects near enough to be benefited by their influences. Whoever imagines they were created only to give a faint glimmering light to the inhabitants of this Globe, muſt have a very ſuperficial knowledge of Aſtronomy, and a mean opinion of the Divine Wiſdom: ſince, by an infinitely leſs exertion of creating power, the Deity could have given our Earth much more light by one ſingle additional Moon.

They are probably ſurrounded by Planets.

9. Inſtead then of one Sun and one World only in the Univerſe, as the unſkilful in Aſtronomy imagine, *that* Science diſcovers to us ſuch an inconceivable number of Suns, Syſtems, and Worlds, diſperſed through boundleſs Space, that if our Sun, with all the Planets, Moons, and Comets belonging to it, were annihilated, they would be no more miſſed, by an eye that could take in the whole Creation, than a grain of ſand from the ſea-ſhore. The ſpace they poſſeſs being comparatively ſo ſmall, that it would ſcarce be a ſenſible blank in the Univerſe, although Saturn, the outermoſt of our Planets, revolves about the Sun in an Orbit of 4884 millions of miles in circumference, and ſome of our Comets make excurſions upwards of ten thouſand millions of miles beyond Saturn's Orbit; and yet, at that amazing diſtance, they are incomparably nearer to the Sun than to any of the Stars; as is evident from their keeping clear of the attractive power of all the Stars, and returning periodically by virtue of the Sun's attraction.

The ſtellar Planets may be habitable,

10. From what we know of our own Syſtem, it may be reaſonably concluded that all the reſt are with equal wiſdom contrived, ſituated, and provided with accommodations for rational inhabitants. Let us therefore take a ſurvey of the Syſtem to which we belong; the only one acceſſible to us; and from thence we ſhall be the better enabled to judge of the nature and end of the other Syſtems of the Univerſe. For although there

Our Moon mountainous like the Earth.

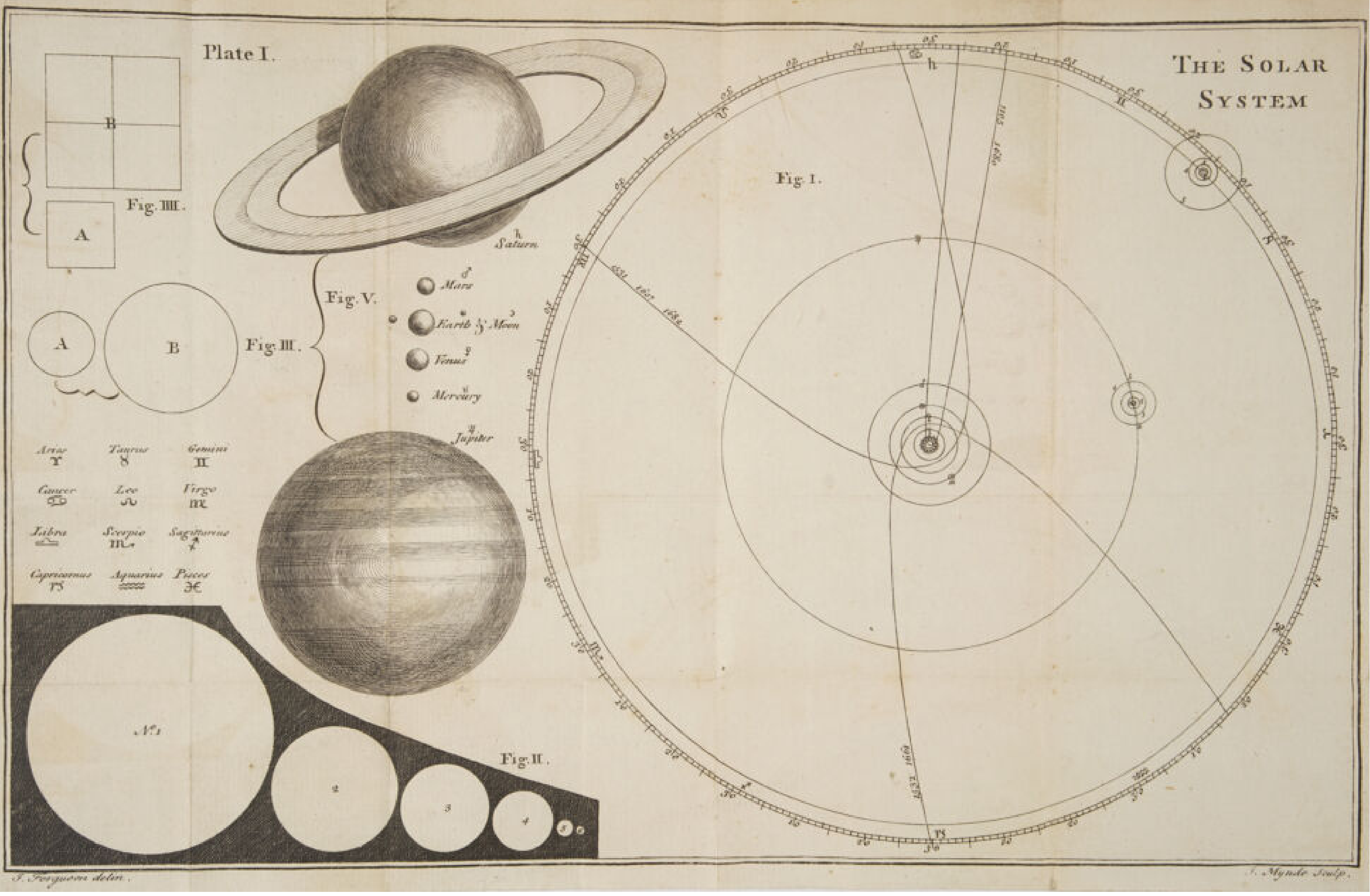
13. On the surface of the Moon, because it is nearer us than any other of the celestial Bodies are, we discover a nearer resemblance of our Earth. For, by the assistance of telescopes, we observe the Moon to be full of high mountains, large valleys, and deep cavities. These similarities leave us no room to doubt, but that all the Planets and Moons in the System are designed as commodious habitations for creatures endowed with capacities of knowing and adoring their beneficent Creator.

14. Since the Fixed Stars are prodigious spheres of fire, like our Sun, and at inconceivable distances from one another, as well as from us, it is reasonable to conclude they are made for the same purposes that the Sun is; each to bestow light, heat, and vegetation on a certain number of inhabited Planets, kept by gravitation within the sphere of it's activity.

Numberless Suns and Worlds.

15. What an august! what an amazing conception, if human imagination can conceive it, does this give of the works of the Creator! Thousands of thousands of Suns, multiplied without end, and ranged all around us, at immense distances from each other, attended by ten thousand times ten thousand Worlds, all in rapid motion, yet calm, regular, and harmonious, invariably keeping the paths prescribed them; and these Worlds peopled with myriads of intelligent beings, formed for endless progression in perfection and felicity.

16. If so much power, wisdom, goodness, and magnificence is displayed in the material Creation, which is the least considerable part of the Universe, how great, how wise, how good must HE be, who made and governs the Whole!



J. Ferguson delin. J. Mynde Sculp.

CHAP. II.

A brief Description of the SOLAR SYSTEM.

17. THE Planets and Comets which move round the SUN as their center, constitute the Solar System. Those Planets which are near the Sun not only finish their circuits sooner, but likewise move faster in their respective Orbits, than those which are more remote from him. Their motions are all performed from west to east, in Orbits nearly circular. Their names, distances, bulks, and periodical revolutions, are as follow. PLATE I. Fig. I. The Solar System.

18. The SUN ☉, an immense globe of fire, is placed near the common center, or rather in the lower * focus, of the Orbits of all the Planets and Comets †; and turns round his axis in 25 days 6 hours, as is evident by the motion of spots seen on his surface. His diameter is computed to be 763,000 miles; and, by the various attractions of the circumvolving Planets, he is agitated by a The Sun. Fig. I.

* If a thread be tied loosely round two pins stuck in a table, and moderately stretched by the point of a black-lead pencil carried round by an even motion and light pressure of the hand, an oval or ellipsis will be described; the two points where the pins are fixed being called the *foci* or focuses thereof. The Orbits of all the Planets are elliptical, and the Sun is placed in or near to one of the *foci* of each of them: and *that* in which he is placed, is called the *lower focus*.

† Astronomers are not far from the truth, when they reckon the Sun's center to be in the lower focus of all the Planetary Orbit. Though strictly speaking, if we consider the focus of Mercury's Orbit to be in the Sun's center, the focus of Venus's Orbit will be in the common center of gravity of the Sun and Mercury; the focus of the Earth's Orbit in the common center of gravity of the Sun, Mercury, and Venus; the focus of the Orbit of Mars in the common center of gravity of the Sun, Mercury, Venus, and the Earth; and so of the rest. Yet, the focuses of the Orbits of all the Planets, except Saturn, will not be sensibly removed from the center of the Sun; nor will the focus of Saturn's Orbit recede sensibly from the common center of gravity of the Sun and Jupiter.

PLATE I. ſmall motion round the center of gravity of the Syſtem. All the Planets, as ſeen from him, move the ſame way, and according to the order of Signs in the graduated Circle ♈ ♉ ♊ ♋ &c. which repreſents the great Ecliptic in the Heavens: but, as ſeen from any one Planet, the reſt appear ſometimes to go backward, ſometimes forward, and ſometimes to ſtand ſtill; not in circles nor ellipſes, but in * looped curves which never return into themſelves. The Comets come from all parts of the Heavens, and move in all ſorts of directions.

19. Having mentioned the Sun's turning round his axis, and as there will be frequent occaſion to ſpeak of the like motion of the Earth and other Planets, it is proper here to inform the young *Tyro* in Aſtronomy, that neither the Sun nor Planets have material axes to turn upon, and ſupport them, as in the little imperfect Machines contrived to repreſent them. For the axis of a Planet is a line conceived to be drawn through it's center, about which it revolves as on a real axis. The extremities of this line, terminating in oppoſite points of the Planet's ſurface, are called it's *Poles*. That which points towards the *northern* part of the Heavens, is called the *North Pole*; and the other, pointing towards the *ſouthern* part, is called the *South Pole*. A bowl whirled from one's hand into the open air turns round ſuch a line within itſelf, whilſt it moves forward; and ſuch are the lines we mean, when we ſpeak of the Axes of the Heavenly bodies.

The Axes of the Planets, what.

Their Orbits are not in the ſame plane with the Ecliptic.

20. Let us ſuppoſe the Earth's Orbit to be a thin, even, ſolid plane; cutting the Sun through the center, and extended out as far as the Starry Heavens, where it will mark the great Circle called the *Ecliptic*. This Circle we ſuppoſe to be divided into 12 equal parts, called *Signs*; each Sign into 30 equal parts, called *Degrees*; each Degree into 60 equal parts, called *Minutes*; and every Minute

* As repreſented in Plate III. Fig. I. and deſcribed § 138.

into

into 60 equal parts, called *Seconds*: ſo that a Second is the 60th part of a Minute; a Minute the 60th part of a Degree; and a Degree the 360th part of a Circle, or 30th part of a Sign. The Planes of the Orbits of all the other Planets likewiſe cut the Sun in halves; but extended to the Heavens, form Circles different from one another, and from the Ecliptic; one half of each being on the north ſide, and the other on the ſouth ſide of it. Conſequently the Orbit of each Planet croſſes the Ecliptic in two oppoſite points, which are called the Planet's *Nodes*. Theſe Nodes are all in different parts of the Ecliptic; and therefore, if the planetary Tracks remained viſible in the Heavens, they would in ſome meaſure reſemble the different ruts of waggon-wheels croſſing one another in different parts, but never going far aſunder. That Node, or Interſection of the Orbit of any Planet with the Earth's Orbit, from which the Planet aſcends northward above the Ecliptic, is called the *Aſcending Node* of the Planet; and the other, which is directly oppoſite thereto, is called it's *Deſcending Node*. Saturn's Aſcending Node is in 21 deg. 13 min. of Cancer ♋, Jupiter's in 7 deg. 29 min. of the ſame Sign, Mars's in 17 deg. 17 min. of Taurus ♉, Venus's in 13 deg. 59 min. of Gemini ♊, and Mercury's in 14 deg. 43 min. of Taurus. Here we conſider the Earth's Orbit as the ſtandard, and the Orbits of all the other Planets as oblique to it.

PLATE I.

Their Nodes.

Where ſituated.

21. When we ſpeak of the Planets Orbits, all that is meant is their Paths through the open and unreſiſting Space in which they move; and are kept in, by the attractive power of the Sun, and the projectile force impreſſed upon them at firſt: between which power and force there is ſo exact an adjuſtment, that they continue in the ſame tracks without any ſolid Orbits to confine them.

The Planets Orbits, what.

22. Mercury, the neareſt Planet to the Sun, goes round him (as in the circle marked ☿) in 87 days

Mercury; Fig. I.

PLATE I. days 23 hours of our time nearly; which is the length of his year. But, being ſeldom ſeen, and no ſpots appearing on his ſurface or diſc, the time of his rotation on his axis, or the length of his days and nights, is as yet unknown. His diſtance from the Sun is computed to be 32 millions of miles, and his diameter 2600. In his courſe, round the Sun, he moves at the rate of 95 thouſand miles every hour. His light and heat from the Sun are almoſt ſeven times as great as ours; and the Sun appears to him almoſt ſeven times as large as to us. The great heat on this Planet is no argument againſt it's being inhabited; ſince the Almighty could as eaſily ſuit the bodies and conſtitutions of it's inhabitants to the heat of their dwelling, as he has done ours to the temperature of our Earth. And it is very probable that the people there have ſuch an opinion of us, as we have of the inhabitants of Jupiter and Saturn; namely, that we muſt be intolerably cold, and have very little light at ſo great a diſtance from the Sun.

May be inhabited.

Has like phaſes with the Moon.

23. This Planet appears to us with all the various phaſes of the Moon, when viewed at different times by a good teleſcope; ſave only that he never appears quite Full, becauſe his enlightened ſide is never turned directly towards us but when he is ſo near the Sun as to be loſt to our ſight in it's beams. And, as his enlightened ſide is always toward the Sun, it is plain that he ſhines not by any light of his own; for if he did, he would conſtantly appear round. That he moves about the Sun in an Orbit within the Earth's Orbit is alſo plain (as will be more largely ſhewn by and by, § 141, *& ſeq.*) becauſe he is never ſeen oppoſite to the Sun, nor above 56 times the Sun's breadth from his center.

His Orbit and Nodes.

24. His Orbit is inclined ſeven degrees to the Ecliptic; and *that* Node, § 20, from which he aſcends northward above the Ecliptic, is in the

14th degree of Taurus; the opposite, in the 14th degree of Scorpio. The Earth is in these points on the 6th of *November* and 4th of *May*, new style; and when Mercury comes to either of his Nodes at his * inferior Conjunction about these times, he will appear to pass over the disc or face of the Sun, like a dark round spot. But in all other parts of his Orbit his Conjunctions are invisible, because he either goes above or below the Sun. PLATE I.

25. Mr. WHISTON has given us an account of several periods at which Mercury may be seen on the Sun's disc, *viz.* In the year 1782, *Nov.* 12th, at 3 h. 44 m. in the afternoon: 1786, *May* 4th, at 6 h. 57 m. in the forenoon: 1789, *Dec.* 6th, at 3 h. 55 m. in the afternoon; and 1799, *May* 7th, at 2 h. 34 m. in the afternoon. There will be several intermediate Transits, but none of them visible at *London*. When he will be seen as if upon the Sun.

26. VENUS, the next Planet in order, is computed to be 59 millions of miles from the Sun; and by moving at the rate of 69 thousand miles every hour in her Orbit (as in the circle marked ♀), she goes round the Sun in 224 days 17 hours of our time nearly; in which, though it be the full length of her year, she has only 9¼ days, according to BIANCHINI's observations; so that in her, every day and night together is as long as 24¼ days and nights with us. This odd quarter of a day in every year makes every fourth year a leap-year to Venus; as the like does to our Earth. Her diameter is 7906 miles; and by her diurnal motion the inhabitants about her Equator are carried 43 miles every hour, besides the 69,000 above-mentioned. Venus. Fig. I.

27. Her Orbit includes that of Mercury within it; for at her greatest Elongation, or apparent distance from the Sun, she is 96 times his breadth Her Orbit lies between the Earth and Mercury.

* When he is between the Earth and the Sun in the nearer part of his Orbit.

from

from his center; which is almoſt double of Mercury's. Her Orbit is included by the Earth's; for if it were not, ſhe might be ſeen as often in Oppoſition to the Sun, as ſhe is in Conjunction with him; but ſhe was never ſeen 90 degrees, or a fourth part of a Circle, from the Sun.

She is our morning and evening Star by turns.

28. When Venus appears weſt of the Sun, ſhe riſes before him in the morning, and is called the *Morning Star*: when ſhe appears eaſt of the Sun, ſhe ſhines in the evening after he ſets, and is then called the *Evening Star*: being each in it's turn for 290 days. It may perhaps be ſurpriſing at firſt, that Venus ſhould keep longer on the eaſt or weſt of the Sun, than the whole time of her Period round him. But the difficulty vaniſhes when we conſider that the Earth is all the while going round the Sun the ſame way, though not ſo quick as Venus: and therefore her relative motion to the Earth muſt in every Period be as much ſlower than her abſolute motion in her Orbit, as the Earth during that time advances forward in the Ecliptic; which is 220 degrees. To us ſhe appears through a teleſcope in all the various ſhapes of the Moon.

29. The Axis of Venus is inclined 75 degrees to the Axis of her Orbit; which is $51\frac{1}{2}$ degrees more than our Earth's Axis is inclined to the Axis of the Ecliptic: and therefore her ſeaſons vary much more than ours do. The North Pole of her Axis inclines toward the 20th degree of Aquarius, our Earth's to the beginning of Cancer; conſequently the northern parts of Venus have ſummer in the Signs where thoſe of our Earth have winter, and *vice versâ*.

Remarkable appearances.

30. The * artificial day at each Pole of Venus is as long as $112\frac{1}{2}$ † natural days on our Earth.

Her Tropics and polar Circles, how ſituated.

31. The Sun's greateſt Declination on each ſide of her Equator amounts to 75 degrees; therefore

* The time between the Sun's riſing and ſetting.

† One entire revolution, or 24 hours.

her

her * Tropics are only 15 degrees from her Poles; and her † Polar Circles as far from her Equator. Conſequently, the Tropics of Venus are between her Polar Circles and her Poles; contrary to what thoſe of our Earth are.

32. As her annual Revolution contains only $9\frac{1}{4}$ of her days, the Sun will always appear to go through a whole Sign, or twelfth Part of her Orbit, in little more than three quarters of her natural day, or nearly in $18\frac{3}{4}$ of our days and nights. The Sun's daily Courſe,

33. Becauſe her day is ſo great a part of her year, the Sun changes his Declination in one day ſo much, that if he paſſes vertically, or directly over head of any given place on the Tropic, the next day he will be 26 degrees from it: and whatever place he paſſes vertically over when in the Equator, one day's revolution will remove him $36\frac{1}{4}$ degrees from it. So that the Sun changes his Declination every day in Venus about 14 degrees more at a mean rate, than he does in a quarter of a year on our Earth. This appears to be providentially ordered, for preventing the too great effects of the Sun's heat (which is twice as great on Venus as on the Earth) ſo that he cannot ſhine perpendicularly on the ſame places for two days together; and by that means, the heated places have time to cool. and great Declination.

34. If the inhabitants about the North Pole of Venus fix their South, or Meridian Line, through that part of the Heavens where the Sun comes to his greateſt Height, or North Declination, and call To determine the points of the Compaſs at her Poles.

* Theſe are leſſer circles parallel to the Equator, and as many degrees from it, towards the Poles, as the Axis of the Planet is inclined to the Axis of it's Orbit. When the Sun is advanced ſo far north or ſouth of the Equator, as to be directly over either Tropic, he goes no farther; but returns towards the other.

† Theſe are leſſer circles round the Poles, and as far from them as the Tropics are from the Equator. The Poles are the very north and ſouth points of the Planet.

thoſe

those the East and West points of their Horizon; which are 90 degrees on each side from that point where the Horizon is cut by the Meridian Line, these inhabitants will have the following remarkables.

The Sun will rise $22\frac{1}{2}$ degrees * north of the East, and going on $112\frac{1}{2}$ degrees, as measured on the plane of the † Horizon, he will cross the Meridian at an altitude of $12\frac{1}{2}$ degrees; then making an entire revolution without setting, he will cross it again at an altitude of $48\frac{1}{2}$ degrees; at the next revolution he will cross the Meridian as he comes to his greatest height and declination, at the altitude of 75 degrees; being then only 15 degrees from the Zenith, or that point of the Heavens which is directly over head: and thence he will descend in the like spiral manner; crossing the Meridian first at the altitude of $48\frac{1}{2}$ degrees; next at the altitude of $12\frac{1}{2}$ degrees; and going on thence $112\frac{1}{2}$ degrees, he will set $22\frac{1}{2}$ degrees north of the West; so that, after having been $4\frac{5}{8}$ revolutions above the Horizon, he descends below it to exhibit the like appearances at the South Pole.

Surprising appearances at her Poles.

35. At each Pole, the Sun continues half a year without setting in summer, and as long without rising in winter; consequently the polar inhabitants of Venus have only one day and one night in the year; as it is at the Poles of our Earth. But the difference between the heat of summer and cold of winter, or of mid-day and mid-night, on Venus, is much greater than on the Earth: because in Venus, as the Sun is for half a year together above the Horizon of each Pole in it's turn, so he is for a considerable part of that time near the Zenith; and during the other half of the year, always below the Horizon, and for a great part of that time at least 70 degrees from it. Whereas, at the

* A Degree is a 360th part of any Circle. See § 21.

† The Limit of any inhabitant's view, where the Sky seems to touch the Planet all round him.

Poles of our Earth, although the Sun is for half a year together above the Horizon; yet he never aſcends above, nor deſcends below it, more than 23½ degrees. When the Sun is in the Equinoctial, or in that Circle which divides the northern half of the Heavens from the ſouthern, he is ſeen with one half of his Diſc above the Horizon of the North Pole, and the other half above the Horizon of the South Pole; ſo that his center is in the Horizon of both Poles: and then deſcending below the Horizon of one, he aſcends gradually above that of the other. Hence, in a year, each Pole has one ſpring, one harveſt, a ſummer as long as them both, and a winter equal in length to the other three ſeaſons.

36. At the Polar Circles of Venus, the ſeaſons are much the ſame as at the Equator, becauſe there are only 15 degrees betwixt them, § 31; only the winters are not quite ſo long, nor the ſummers ſo ſhort: but the four ſeaſons come twice round every year. At her polar Circles.

37. At Venus's Tropics, the Sun continues for about fifteen of our weeks together without ſetting in ſummer; and as long without riſing in winter. Whilſt he is more than 15 degrees from the Equator, he neither riſes to the inhabitants of the one Tropic, nor ſets to thoſe of the other: whereas, at our terreſtrial Tropics, he riſes and ſets every day of the year. At her Tropics.

38. At Venus's Tropics, the Seaſons are much the ſame as at her Poles; only the ſummers are a little longer, and the winters a little ſhorter.

39. At her Equator, the days and nights are always of the ſame length; and yet the diurnal and nocturnal Arches are very different, eſpecially when the Sun's declination is about the greateſt: for then, his meridian altitude may ſometimes be twice as great as his midnight depreſſion, and at other times the reverſe. When the Sun is at his greateſt Declination, either North or South, his At her Equator.

rays are as oblique at Venus's Equator, as they are at *London* on the ſhorteſt day of winter. Therefore, at her Equator there are two winters, two ſummers, two ſprings, and two autumns every year. But becauſe the Sun ſtays for ſome time near the Tropics, and paſſes ſo quickly over the Equator, every winter there will be almoſt twice as long as ſummer: the four ſeaſons returning twice in that time, which conſiſts only of 9¼ days.

40. Thoſe parts of Venus which lie between the Poles and Tropics, and between the Tropics and Polar Circles, and alſo between the Polar Circles and Equator, partake more or leſs of the Phenomena of theſe Circles, as they are more or leſs diſtant from them.

Great difference of the Sun's amplitude at riſing and ſetting.

41. From the quick change of the Sun's declination it happens, that if he riſes due eaſt on any day, he will not ſet due weſt on that day, as with us; for if the place where he riſes due eaſt be on the Equator, he will ſet on that day almoſt weſt-north-weſt; or about 18½ degrees north of the weſt. But if the place be in 45 degrees north latitude, then on the day that the Sun riſes due eaſt he will ſet north-weſt by weſt, or 33 degrees north of the weſt. And in 62 degrees north latitude, when he riſes in the eaſt, he ſets not in that revolution, but juſt touches the Horizon 10 degrees to the weſt of the north point; and aſcends again, continuing for 3¼ revolutions above the Horizon without ſetting. Therefore, no place has the forenoon and afternoon of the ſame day equally long, unleſs it be in the Equator, or at the Poles.

The longitude of places eaſily found in Venus.

42. The Sun's altitude at noon, or any other time of the day, and his amplitude at riſing and ſetting, being very different at places on the ſame parallel of latitude, according to the different longitudes of thoſe places, the longitude will be almoſt as eaſily found on Venus, as the latitude is found on the Earth: which is an advantage we can never enjoy, becauſe the daily change of the Sun's declination

nation is by much too ſmall for that important purpoſe.

43. On this Planet, where the Sun croſſes the Equator in any year, he will have 9 degrees of declination from that place on the ſame day and hour next year; and will croſs the Equator 90 degrees farther to the weſt; which makes the time of the Equinox a quarter of a day (or about ſix of our days) later every year. Hence, although the ſpiral in which the Sun's motion is performed, be of the ſame ſort every year, yet it will not be the very ſame, becauſe the Sun will not paſs vertically over the ſame places till four annual revolutions are finiſhed. Her Equinoxes ſhift a quarter of a day forward every year.

44. We may ſuppoſe that the inhabitants of Venus will be careful to add a day to ſome particular part of every fourth year; which will keep the ſame ſeaſons to the ſame days. For, as the great annual change of the Equinoxes and Solſtices ſhifts the ſeaſons a quarter of a day every year, they would be ſhifted through all the days of the year in 36 years. But by means of this intercalary day, every fourth year will be a leap-year; which will bring her time to an even reckoning, and keep her Calender always right. Every fourth year a leap-year to Venus.

45. Venus's Orbit is inclined $3\frac{1}{2}$ degrees to the Earth's; and croſſes it in the 14th degree of Gemini and of Sagittarius; and therefore, when the Earth is about theſe points of the Ecliptic at the time that Venus is in her inferior conjunction, ſhe will appear like a ſpot on the Sun, and afford a more certain method of finding the diſtances of all the Planets from the Sun, than any other yet known. But theſe appearances happen very ſeldom; and will only be twice viſible at *London* for one hundred and ten years to come. The firſt time will be in the year 1761, *June* the 6th, in the morning; and the ſecond, on the 3d of *June* in the evening. Excepting ſuch Tranſits as theſe, ſhe ſhews the ſame appearances to us regularly When ſhe will appear on the Sun.

every eight years; her Conjunctions, Elongations, and Times of riſing and ſetting, being very nearly the ſame, on the ſame days, as before.

She may have a Moon, although we cannot ſee it.

46. Venus may have a Satellite or Moon, although it be undiſcovered by us: which will not appear very ſurpriſing, if we conſider how inconveniently we are placed for ſeeing it. For it's enlightened ſide can never be fully turned towards us, but when Venus is beyond the Sun; and then, as Venus appears little bigger than an ordinary Star, her Moon may be too ſmall to be perceived at ſuch a diſtance. When ſhe is between us and the Sun, her full Moon has it's dark ſide towards us; and then we cannot ſee it any more than we can our own Moon at the time of Change. When Venus is at her greateſt Elongation, we have but one half of the enlightened ſide of her Full Moon towards us; and even then it may be too far diſtant to be ſeen by us. But if ſhe has a Moon, it may certainly be ſeen with her upon the Sun, in the year 1761, unleſs it's Orbit be conſiderably inclined to the Ecliptic: for if it ſhould be in conjunction or oppoſition at that time, we can hardly imagine that it moves ſo ſlow as to be hid by Venus all the ſix hours that ſhe will appear on the Sun's Diſc *.

The Earth.

Fig. I.

47. The EARTH is the next Planet above Venus in the Syſtem. It is 82 millions of miles from the Sun, and goes round him (as in the circle ⊕) in 365 days 5 hours 49 minutes, from any Equinox or Solſtice to the ſame again: but from any fixed Star to the ſame again, as ſeen from the Sun, in 365 days 6 hours and 9 minutes; the former being the length of the Tropical year, and the latter the length of the Sydereal. It travels at the rate of 58 thouſand miles every hour; which motion, though 120 times ſwifter than that of a

It's diurnal and annual motion.

* The tranſit is over ſince this was wrote, and no Satellite was ſeen with Venus on the Sun's Diſc.

cannon-

cannon-ball, is little more than half as swift as Mercury's motion in his Orbit. The Earth's diameter is 7970 miles; and by turning round it's Axis every 24 hours from West to East, it causes an apparent diurnal motion of all the heavenly Bodies from East to West. By this rapid motion of the Earth on it's Axis, the inhabitants about the Equator are carried 1042 miles every hour, whilst those on the parallel of *London* are carried only about 580, besides the 58 thousand miles by the annual motion above-mentioned, which is common to all places whatever.

48. The Earth's Axis makes an angle of $23\frac{1}{2}$ degrees with the Axis of it's Orbit; and keeps always the same oblique direction; inclining towards the same fixed Stars * throughout it's annual course; which causes the returns of spring, summer, autumn, and winter; as will be explained at large in the tenth Chapter. Inclination of it's Axis.

49. The Earth is round like a globe; as appears, 1. By it's shadow in Eclipses of the Moon; which shadow is always bounded by a circular line, § 314. 2. By our seeing the masts of a ship whilst the hull is hid by the convexity of the water. 3. By it's having been sailed round by many navigators. The hills take off no more from the roundness of the Earth in comparison, than grains of dust do from the roundness of a common Globe. A proof of it's being round.

50. The seas and unknown parts of the Earth (by a measurement of the best Maps) contain 160 million 522 thousand and 26 square miles; the inhabited parts 38 million 990 thousand 569: *Europe* 4 million 456 thousand and 65; *Asia* 10 It's number of square miles.

* This is not strictly true, as will appear when we come to treat of the Recession of the Equinoctial Points in the Heavens, § 246; which recession is equal to the deviation of the Earth's Axis from it's parallelism: but this is rather too small to be sensible in an age, except to those who make very nice observations.

million 768 thouſand 823; *Africa* 9 million 654 thouſand 807; *America* 14 million 110 thouſand 874. In all, 199 million 512 thouſand 595; which is the number of ſquare miles on the whole ſurface of our Globe.

The proportion of land and ſea. 51. Dr. LONG, in the firſt volume of his Aſtronomy, p. 168, mentions an ingenious and eaſy method of finding nearly what proportion the land bears to the ſea; which is, to take the papers of a large terreſtrial globe, and after ſeparating the land from the ſea with a pair of ſciſſars, to weigh them carefully in ſcales. This ſuppoſes the globe to be exactly delineated, and the papers all of equal thickneſs. The Doctor made the experiment on the papers of Mr. SENEX's ſeventeen-inch globe; and found that the ſea papers weighed 349 grains, and the land only 124: by which it appears that almoſt three fourth parts of the ſurface of our Earth between the Polar Circles are covered with water, and that little more than one fourth is dry land. The Doctor omitted weighing all within the Polar Circles; becauſe there is no certain meaſurement of the land within them, ſo as to know what proportion it bears to the ſea.

The Moon. 52. The MOON is not a Planet, but only a Satellite or Attendant of the Earth; going round the Earth from Change to Change in 29 days 12 hours and 44 minutes; and round the Sun with it every year. The Moon's diameter is 2180 miles; and her diſtance from the Earth's center 240 thouſand. She goes round her Orbit in 27 days 7 hours 43 minutes, moving about 2290 miles every hour; and turns round her Axis exactly in the time that ſhe goes round the Earth, which is the reaſon of her keeping always the ſame ſide towards us, and that her day and night taken together is as long as our lunar month.

53. The Moon is an opaque Globe like the Earth, and ſhines only by reflecting the light of

the Sun: therefore whilst that half of her which is towards the Sun is enlightened, the other half must be dark and invisible. Hence, she disappears when she comes between us and the Sun; because her dark side is then towards us. When she is gone a little way forward, we see a little of her enlightened side; which still increases to our view, as she advances forward, until she comes to be opposite to the Sun; and then her whole enlightened side is towards the Earth, and she appears with a round, illumined Orb, which we call the *Full Moon:* her dark side being then turned away from the Earth. From the Full she seems to decrease gradually as she goes through the other half of her course; shewing us less and less of her enlightened side every day, till her next change or conjunction with the Sun, and then she disappears as before. Her Phases.

54. This continual change of the Moon's phases demonstrates that she shines not by any light of her own: for if she did, being globular, we should always see her with a round full Orb like the Sun. Her Orbit is represented in the Scheme by the little circle *m*, upon the Earth's Orbit ⊕: but it is drawn fifty times too large in proportion to the Earth's; and yet is almost too small to be seen in the Diagram. A proof that she shines not by her own light. Fig. I.

55. The Moon has scarce any difference of seasons; her Axis being almost perpendicular to the Ecliptic. What is very singular, one half of her has no darkness at all; the Earth constantly affording it a strong light in the Sun's absence; while the other half has a fortnight's darkness and a fortnight's light by turns. One half of her always enlightened.

56. Our Earth is a Moon to the Moon, waxing and waneing regularly, but appearing thirteen times as big, and affording her thirteen times as much light, as she does to us. When she changes to us, the Earth appears full to her; and when she is in her first quarter to us, the Earth is in it's third quarter to her; and *vice versâ*. Our Earth is her Moon.

57. But from one half of the Moon, the Earth is never seen at all: from the middle of the other half, it is always seen over head; turning round almost thirty times as quick as the Moon does. From the circle which limits our view of the Moon, only one half of the Earth's side next her is seen; the other half being hid below the Horizon of all places on that circle. To her, the Earth seems to be the biggest body in the Universe; for it appears thirteen times as big as she does to us.

58. The Moon has no Atmosphere of any visible density surrounding her as we have: for if she had, we could never see her edge so well defined as it appears; but there would be a sort of a mist or haziness around her, which would make the Stars look fainter, when they are seen through it. But observation proves, that the Stars which disappear behind the Moon, retain their full lustre until they seem to touch her very edge, and then they vanish in a moment. This has been often observed by Astronomers, but particularly by Cassini* of the Star γ in the breast of Virgo, which appears single and round to the bare eye; but through a refracting Telescope of 16 feet appears to be two Stars so near together, that the distance between them seems to be but equal to one of their apparent diameters. The Moon was observed to pass over them on the 21st of *April*, 1720, *N. S.* and as her dark edge drew near to them, it caused no change in their colour or situation. At 25 min. 14 sec. past 12 at night, the most westerly of these Stars was hid by the dark edge of the Moon; and in 30 seconds afterward, the most easterly Star was hid: each of them disappearing behind the Moon in an instant, without any preceding diminution of magnitude or brightness; which by no means could have been the case if there were an Atmosphere round the Moon; for then, one of the Stars falling obliquely into it before the other, ought by

A Proof of the Moon's having no Atmosphere.

* *Memoires d'Acad. ann.* 1720.

refraction

refraction to have suffered some change in it's colour, or in it's distance from the other Star which was not yet entered into the Atmosphere. But no such alteration could be perceived, though the observation was performed with the utmost attention to that particular; and was very proper to have made such a discovery. The faint light, which has been seen all round the Moon, in total Eclipses of the Sun, has been observed, during the time of darkness, to have it's center coincident with the center of the Sun; and was therefore much more likely to arise from the Atmosphere of the Sun, than from that of the Moon; for if it had been owing to the latter, it's center would have gone along with the Moon's.

59. If there were seas in the Moon, she could have no clouds, rains, nor storms, as we have; because she has no such Atmosphere to support the vapours which occasion them. And every one knows, that when the Moon is above our Horizon in the night-time, she is visible, unless the clouds of our Atmosphere hide her from our view; and all parts of her appear constantly with the same clear, serene, and calm aspect. But those dark parts of the Moon, which were formerly thought to be seas, are now found to be only vast deep cavities, and places which reflect not the Sun's light so strongly as others, having many caverns and pits whose shadows fall within them, and are always dark on the sides next the Sun; which demonstrates their being hollow: and most of these pits have little knobs like hillocks standing within them, and casting shadows also; which cause these places to appear darker than others which have fewer, or less remarkable caverns. All these appearances shew that there are no seas in the Moon; for if there were any, their surfaces would appear smooth and even, like those on the Earth. Nor Seas. She is full of caverns and deep pits.

60. There being no Atmosphere about the Moon, the heavens in the day-time have the appearance The Stars always visible to the Moon.

pearance of night to a Lunarian who turns his back toward the Sun; and when he does, the Stars appear as bright to him as they do in the night to us. For, it is entirely owing to our Atmoſphere that the Heavens are bright about us in the day.

61. As the Earth turns round it's Axis, the ſeveral continents, ſeas, and iſlands appear to the Moon's inhabitants like ſo many ſpots of different forms and brightneſs, moving over it's ſurface; but much fainter at ſome times than others, as our clouds cover them or leave them. By theſe ſpots the Lunarians can determine the time of the Earth's diurnal motion, juſt as we do the motion of the Sun: and perhaps they meaſure their time by the motion of the Earth's ſpots; for they cannot have a truer dial.

The Earth a Dial to the Moon.

62. The Moon's Axis is ſo nearly perpendicular to the Ecliptic, that the Sun never removes ſenſibly from her Equator: and the * obliquity of her Orbit, which is next to nothing as ſeen from the Sun, cannot cauſe the Sun to decline ſenſibly from her Equator. Yet her inhabitants are not deſtitute of means for aſcertaining the length of their year, though their method and ours muſt differ. For we can know the length of our year by the return of our Equinoxes; but the Lunarians, having always equal day and night, muſt have recourſe to another method; and we may ſuppoſe, they meaſure their year by obſerving when either of the Poles of our Earth begins to be enlightened, and the other to diſappear, which is always at our Equinoxes; they being conveniently ſituated for obſerving great tracks of land about our Earth's Poles, which are entirely unknown to us. Hence we may conclude, that the year is of the ſame abſolute length both to the

How the Lunarians may know the length of their year,

* The Moon's Orbit croſſes the Ecliptic in two oppoſite points, called the Moon's Nodes; ſo that one half of her Orbit is above the Ecliptic, and the other half below it. The Angle of it's Obliquity is $5\frac{1}{3}$ degrees.

Earth

Earth and Moon, though very different as to the number of days: we having 365¼ natural days, and the Lunarians only 12$\frac{7}{19}$; every day and night in the Moon being as long as 29½ on the Earth. PLATE I.

63. The Moon's inhabitants on the ſide next the Earth may as eaſily find the longitude of their places as we can find the latitude of ours. For the Earth keeping conſtantly, or very nearly ſo, over one Meridian of the Moon, the eaſt or weſt diſtances of places from that Meridian are as eaſily found, as we can find our diſtance from the Equator by the Altitude of our celeſtial Poles. and the longitudes of their places.

64. The Planet MARS is next in order, being the firſt above the Earth's Orbit. His diſtance from the Sun is computed to be 125 millions of miles; and by travelling at the rate of 47 thouſand miles every hour, as in the circle ♂, he goes round the Sun in 686 of our days and 23 hours; which is the length of his year, and contains 667¾ of his days; every day and night together being 40 minutes longer than with us. His diameter is 4444 miles, and by his diurnal rotation the inhabitants about his Equator are carried 556 miles every hour. His quantity of light and heat is equal but to one half of ours; and the Sun appears but half as big to him as to us. Mars. Fig. I.

65. This Planet being but a fifth part ſo big as the Earth, if any Moon attends him, ſhe muſt be very ſmall, and has not yet been diſcovered by our beſt teleſcopes. He is of a fiery red colour, and by his Appulſes to ſome of the fixed Stars, ſeems to be encompaſſed by a very groſs Atmoſphere. He appears ſometimes gibbous, but never horned; which both ſhews that his Orbit includes the Earth's within it, and that he ſhines not by his own light. His Atmoſphere and Phaſes.

66. To Mars, our Earth and Moon appear like two Moons, a bigger and a leſs; changing places with one another, and appearing ſometimes horned,

horned, ſometimes half or three quarters illuminated, but never full; nor at moſt above one quarter of a degree from each other, although they are 240 thouſand miles aſunder.

How the other Planets appear to Mars.

67. Our Earth appears almoſt as big to Mars as Venus does to us, and at Mars it is never ſeen above 48 degrees from the Sun; ſometimes it appears to paſs over the Diſc of the Sun, and ſo do Mercury and Venus: but Mercury can never be ſeen from Mars by ſuch eyes as ours, unaſſiſted by proper inſtruments; and Venus will be as ſeldom ſeen as we ſee Mercury. Jupiter and Saturn are as viſible to Mars as to us. His Axis is perpendicular to the Ecliptic, and his Orbit is 2 degrees inclined to it.

Jupiter.

68. JUPITER, the biggeſt of all the Planets, is ſtill higher in the Syſtem, being about 426 millions of miles from the Sun: and going at the rate of 25 thouſand miles every hour in his Orbit, as in the circle ♃, finiſhes his annual period in eleven of our years 314 days and 12 hours. He is above 1000 times as big as the Earth, for his diameter is 81,000 miles; which is more than ten times the diameter of the Earth. (Fig. I.)

The number of days in his year.

69. Jupiter turns round his Axis in 9 hours 56 minutes; ſo that his year contains 10 thouſand 470 days; and the diurnal velocity of his equatoreal parts is greater than the ſwiftneſs with which he moves in his annual Orbit; a ſingular circumſtance, as far as we know. By this prodigious quick Rotation, his equatoreal inhabitants are carried 25 thouſand 920 miles every hour (which is 920 miles an hour more than an inhabitant of our Earth's equator moves in twenty-four hours) beſides the 25 thouſand above-mentioned, which is common to all parts of his ſurface, by his annual motion.

His Belts and ſpots.

70. Jupiter is ſurrounded by faint ſubſtances, called *Belts*, in which ſo many changes appear,

that they are generally thought to be clouds: for ſome of them have been firſt interrupted and broken, and then have vaniſhed entirely. They have ſometimes been obſerved of different breadths, and afterwards have all become nearly of the ſame breadth. Large ſpots have been ſeen in theſe Belts; and when a Belt vaniſhes, the contiguous ſpots diſappear with it. The broken ends of ſome Belts have been generally obſerved to revolve in the ſame time with the ſpots; only thoſe nearer the Equator in ſomewhat leſs time than thoſe near the Poles; perhaps on account of the Sun's greater heat near the Equator, which is parallel to the Belts and courſe of the ſpots. Several large ſpots, which appear round at one time, grow oblong by degrees, and then divide into two or three round ſpots. The periodical time of the ſpots near the Equator is 9 hours 50 minutes, but of thoſe near the Poles 9 hours 56 minutes. *See Dr.* SMITH's *Optics*, § 1004, *&* *ſeq.*

71. The Axis of Jupiter is ſo nearly perpendicular to his Orbit, that he has no ſenſible change of ſeaſons; which is a great advantage, and wiſely ordered by the Author of Nature. For, if the Axis of this Planet were inclined any conſiderable number of degrees, juſt ſo many degrees round each Pole would in their turn be almoſt ſix of our years together in darkneſs. And, as each degree of a great Circle on Jupiter contains 706 of our miles at a mean rate, it is eaſy to judge what vaſt tracts of land would be rendered uninhabitable by any conſiderable inclination of his Axis. He has no change of ſeaſons;

72. The Sun appears but $\frac{1}{27}$ part ſo big to Jupiter as to us; and his light and heat are in the ſame ſmall proportion, but compenſated by the quick returns thereof, and by four Moons (ſome bigger and ſome leſs than our Earth) which revolve about him: ſo that there is ſcarce any part of this huge Planet but what is during the whole night enlightened by one or more of theſe Moons, but has four Moons.

except

except his Poles, whence only the fartheſt Moons can be ſeen, and where their light is not wanted, becauſe the Sun conſtantly circulates in or near the Horizon, and is very probably kept in view of both Poles by the refraction of Jupiter's Atmoſphere, which, if it be like ours, has certainly refractive power enough for that purpoſe.

Their periods round Jupiter.

73. The Orbits of theſe Moons are repreſented in the Scheme of the Solar Syſtem by four ſmall circles marked 1. 2. 3. 4. on Jupiter's Orbit ♃; but they are drawn fifty times too large in proportion to it. The firſt Moon, or that neareſt to Jupiter, goes round him in 1 day 18 hours and 36 minutes of our time; and is 229 thouſand miles diſtant from his center: The ſecond performs it's revolution in three days 13 hours and 15 minutes, at 364 thouſand miles diſtance: The third in 7 days three hours and 59 minutes, at the diſtance of 580 thouſand miles: And the fourth, or outermoſt, in 16 days 18 hours and 30 minutes, at the diſtance of one million of miles from his center.

Parallax of their Orbits, and diſtances from Jupiter.

74. The Angles under which the Orbits of Jupiter's Moons are ſeen from the Earth, as it's mean diſtance from Jupiter, are as follow: The firſt, 3′ 55″; the ſecond, 6′ 14″; the third, 9′ 58″; and the fourth, 17′ 30″. And their diſtances from Jupiter, meaſured by his ſemidiameters, are thus: The firſt, $5\frac{2}{3}$; the ſecond, 9; the third, $14\frac{23}{60}$; and the fourth, $25\frac{18}{60}$ *. This Planet, ſeen from it's neareſt Moon, appears 1000 times as large as our Moon does to us; waxing and waneing in all her monthly ſhapes, every $42\frac{1}{2}$ hours.

How he appears to his neareſt Moon.

Two grand diſcoveries made by the Eclipſe of Jupiter's Moons.

75. Jupiter's three neareſt Moons fall into his ſhadow, and are eclipſed in every Revolution: but the Orbit of the fourth Moon is ſo much inclined, that it paſſeth by it's oppoſition to Jupiter, without falling into his ſhadow, two years in every ſix. By theſe Eclipſes, Aſtronomers have not only diſ-

* CASSINI *Elements d'Aſtronomie, Liv.* ix. *Chap.* 3.

covered

covered that the Sun's light takes up eight minutes of time in coming to us; but they have alſo determined the longitudes of places on this Earth with greater certainty and facility, than by any other method yet known; as ſhall be explained in the eleventh Chapter. PLATE I.

76. The difference between the Equatoreal and Polar diameters of Jupiter is 6230 miles; for his equatoreal diameter is to his polar, as 13 to 12. So that his Poles are 3115 miles nearer his center than his Equator is. This reſults from his quick motion round his Axis; for the fluids, together with the light particles, which they can carry or waſh away with them, recede from the Poles which are at reſt, towards the Equator where the motion is quickeſt, until there be a ſufficient number accumulated to make up the deficiency of gravity loſt by the centrifugal force, which always ariſes from a quick motion round an axis: and when the deficiency of weight or gravity of the particles is made up by a ſufficient accumulation, there is an *equilibrium*, and the equatoreal parts riſe no higher. Our Earth being but a very ſmall Planet compared to Jupiter, and it's motion on it's Axis being much ſlower, it is leſs flattened of courſe; for the difference between it's equatoreal and polar diameters is only as 230 to 229, namely, 35 miles.

The great difference between the Equatoreal and Polar diameters of Jupiter.

The difference little in thoſe of our Earth.

77. Jupiter's Orbit is 1 degree 20 minutes inclined to the Ecliptic. His North Node is in the 7th degree of Cancer, and his South Node in the 7th degree of Capricorn.

Place of his Nodes.

78. SATURN, the remoteſt of all the Planets, is about 780 millions of miles from the Sun; and, travelling at the rate of 18 thouſand miles every hour, as in the circle marked ♄, performs it's annual circuit in 29 years 167 days and 5 hours of our time; which makes only one year to that Planet. It's diameter is 67,000 miles; and therefore it is near 600 times as big as the Earth.

Saturn. Fig. I.

79. This

PLATE I. Fig. V. His Ring.

79. This Planet is surrounded by a thin broad Ring, as an artificial Globe is by a Horizon. The Ring appears double when seen through a good telescope, and is represented by the figure in such an oblique view as it is generally seen. It is inclined 30 degrees to the Ecliptic, and is about 21 thousand miles in breath; which is equal to it's distance from Saturn on all sides. There is reason to believe that the Ring turns round it's Axis, because, when it is almost edge-wise to us, it appears somewhat thicker on one side of the Planet than on the other; and the thickest edge has been seen on different sides at different times. But Saturn having no visible spots on his body, whereby to determine the time of his turning round his Axis, the length of his days and nights, and the position of his Axis, are unknown to us.

80. To Saturn, the Sun appears only $\frac{1}{90}$th part so big as to us; and the light and heat he receives from the Sun are in the same proportion to ours.

His five Moons.

But to compensate for the small quantity of sun-light, he has five Moons, all going round him on the outside of his Ring, and nearly in the same plane with it. The first, or nearest Moon to Saturn, goes round him in 1 day 21 hours 19 minutes; and is 140 thousand miles from his center: The second, in 2 days 17 hours 40 minutes; at the distance of 187 thousand miles: The third, in 4 days 12 hours 25 minutes; at 263 thousand miles distance: The fourth, in 15 days 22 hours 41 minutes; at the distance of 600 thousand miles: And the fifth, or outermost, at one million 800 thousand miles from Saturn's center, goes round him in 79 days 7 hours 48 minutes. Their

Fig. I.

Orbits in the Scheme of the Solar System are represented by the five small circles, marked 1. 2. 3. 4. 5. on Saturn's Orbit; but these, like the Orbits of the other Satellites, are drawn fifty times too large in proportion to the Orbits of their Primary Planets.

81. The

81. The Sun ſhines almoſt fifteen of our years together on one ſide of Saturn's Ring without ſetting, and as long on the other in it's turn. So that the Ring is viſible to the inhabitants of that Planet for almoſt fifteen of our years, and as long inviſible by turns, if it's Axis has no Inclination to it's Ring: but if the Axis of the Planet be inclined to the Ring, ſuppoſe about 30 degrees, the Ring will appear and diſappear once every natural day to all the inhabitants within 30 degrees of the Equator, on both ſides, frequently eclipſing the Sun in a Saturnian day. Moreover, if Saturn's Axis be ſo inclined to his Ring, it is perpendicular to his Orbit; and thereby the inconvenience of different ſeaſons to that Planet is avoided. For conſidering the length of Saturn's year, which is almoſt equal to thirty of ours, what a dreadful condition muſt the inhabitants of his Polar regions be in, if they be half that time deprived of the light and heat of the Sun? which is not their caſe alone, if the Axis of the Planet be perpendicular to the Ring, for then the Ring muſt hide the Sun from vaſt tracks of land on each ſide of the Equator for 13 or 14 of our years together, on the ſouth ſide and north ſide by turns, as the Axis inclines to or from the Sun: the reverſe of which inconvenience is another good preſumptive proof of the Inclination of Saturn's Axis to it's Ring, and alſo of his Axis being perpendicular to his Orbit.

His Axis probably inclined to his Ring.

82. This Ring, ſeen from Saturn, appears like a vaſt luminous Arch in the Heavens, as if it did not belong to the Planet. When we ſee the Ring moſt open, it's ſhadow upon the Planet is broadeſt; and from that time the ſhadow grows narrower, as the Ring appears to do to us; until, by Saturn's annual motion, the Sun comes to the plane of the Ring, or even with it's edge; which being then directed towards us, becomes inviſible on account of it's thinneſs; as ſhall be explained more largely

How the Ring appears to Saturn and to us.

in

In what Signs Saturn appears to loſe his Ring; and in what Signs it appears moſt open to us.

in the tenth Chapter, and illuſtrated by a figure. The Ring diſappears twice in every annual Revolution of Saturn, namely, when he is in the 19th degree both of Piſces and of Virgo. And when Saturn is in the middle between theſe points, or in the 19th degree either of Gemini or of Sagittarius, his Ring appears moſt open to us; and then it's longeſt diameter is to it's ſhorteſt, as 9 to 4.

No Planet but Saturn can be ſeen from Jupiter; nor any from Jupiter beſides Saturn.

83. To ſuch Eyes as ours, unaſſiſted by inſtruments, Jupiter is the only Planet that can be ſeen from Saturn; and Saturn the only Planet that can be ſeen from Jupiter. So that the inhabitants of theſe two Planets muſt either ſee much farther than we do, or have equally good inſtruments to carry their ſight to remote objects, if they know that there is ſuch a body as our Earth in the Univerſe: for the Earth is no bigger ſeen from Jupiter, than his Moons are ſeen from the Earth; and if his large body had not firſt attracted our ſight, and prompted our curioſity to view him with the teleſcope, we ſhould never have known any thing of his Moons; unleſs by chance we had directed the teleſcope toward that ſmall part of the Heavens where they were at the time of obſervation. And the like is true of the Moons of Saturn.

Place of Saturn's Nodes.

84. The Orbit of Saturn is $2\frac{1}{2}$ degrees inclined to the Ecliptic, or Orbit of our Earth, and interſects it in the 21ſt degree of Cancer and of Capricorn; ſo that Saturn's Nodes are only 14 degrees from Jupiter's, § 77.

The Sun's light much ſtronger on Jupiter and Saturn than is generally believed.

85. The quantity of light, afforded by the Sun to Jupiter, being but $\frac{1}{28}$th part, and to Saturn only $\frac{1}{90}$th part, of what we enjoy; may at firſt thought induce us to believe that theſe two Planets are entirely unfit for rational beings to dwell upon. But, that their light is not ſo weak as we imagine, is evident from their brightneſs in the night-time; and alſo from this remarkable Phenomenon, that when the Sun is ſo much eclipſed to us, as to have only

only the 40th part of his disc left uncovered by the Moon, the decrease of light is not very sensible: and just at the end of darkness in Total Eclipses, when his western limb begins to be visible, and seems no bigger than a bit of fine silver wire, every one is surprised at the brightness wherewith that small part of him shines. The Moon when Full affords travellers light enough to keep them from mistaking their way; and yet, according to Dr. SMITH*, it is equal to no more than a 90 thousandth part of the light of the Sun: that is, the Sun's light is 90 thousand times as strong as the light of the Moon when Full. Consequently, the Sun gives a thousand times as much light to Saturn as the Full Moon does to us; and above three thousand times as much to Jupiter. So that these two Planets, even without any Moons, would be much more enlightened than we at first imagine; and by having so many, they may be very comfortable places of residence. Their heat, so far as it depends on the force of the Sun's rays, is certainly much less than ours; to which no doubt the bodies of their inhabitants are as well adapted as ours are to the seasons we enjoy. And if we consider, that Jupiter never has any winter, even at his Poles; which probably is also the case with Saturn, the cold cannot be so intense on these two Planets as is generally imagined. Besides, there may be something in their nature or soil much warmer than in that of our Earth: and we find that all our heat depends not on the rays of the Sun; for if it did, we should always have the same months equally hot or cold at their annual returns. But it is far otherwise, for *February* is sometimes warmer than *May*; which must be owing to vapours and exhalations from the Earth.

All our heat depends not on the Sun's rays.

86. Every person who looks upon, and compares the Systems of Moons together, which belong to

* Optics, Art. 95.

Jupiter and Saturn, muſt be amazed at the vaſt magnitude of theſe two Planets, and the noble attendance they have in reſpect of our little Earth: and can never bring himſelf to think, that an infinitely wiſe Creator ſhould diſpoſe of all his animals and vegetables here, leaving the other Planets bare and deſtitute of rational creatures. To ſuppoſe that he had any view to our benefit, in creating theſe Moons and giving them their motions round Jupiter and Saturn; to imagine that he intended theſe vaſt Bodies for any advantage to us, when he well knew that they could never be ſeen but by a few Aſtronomers peeping through teleſcopes; and that he gave to the Planets regular returns of days and nights, and different ſeaſons to all where they would be convenient; but of no manner of ſervice to us, except only what immediately regards our own Planet the Earth; to imagine, I ſay, that he did all this on our account, would be charging him impiouſly with having done much in vain: and as abſurd, as to imagine that he has created a little Sun and a Planetary Syſtem within the Shell of our Earth, and intended them for our uſe. Theſe conſiderations amount to little leſs than a poſitive proof, that all the Planets are inhabited: for if they are not, why all this care in furniſhing them with ſo many Moons, to ſupply thoſe with light which are at the greater diſtances from the Sun? Do we not ſee, that the farther a Planet is from the Sun, the greater Apparatus it has for that purpoſe? ſave only Mars, which being but a ſmall Planet, may have Moons too ſmall to be ſeen by us. We know that the Earth goes round the Sun, and turns round it's own Axis, to produce the viciſſitudes of ſummer and winter by the former, and of day and night by the latter motion, for the benefit of it's inhabitants. May we not then fairly conclude, by parity of reaſon, that the end and deſign of all the other Planets, is the ſame? and is not this agreeable to the beautiful

It is highly probable that all the Planets are inhabited.

harmony which exiſts throughout the Univerſe? PLATE I.
Surely it is: and raiſes in us the moſt magnificent ideas of the SUPREME BEING, who is every where, and at all times preſent; diſplaying his power, wiſdom and goodneſs, among all his creatures! and diſtributing happineſs to innumerable ranks of various beings!

87. In Fig. 2d, we have a view of the proportional breadth of the Sun's face or diſc, as ſeen from the different Planets. The Sun is repreſented N° 1, as ſeen from Mercury; N° 2, as ſeen from Venus; N° 3, as ſeen from the Earth; N° 4, as ſeen from Mars; N° 5, as ſeen from Jupiter; and N° 6, as ſeen from Saturn. Fig. II. How the Sun appears to the different Planets.

Let the circle *B* be the Sun as ſeen from any Planet, at a given diſtance; to another Planet, at double that diſtance, the Sun will appear juſt of half that breadth, as *A*; which contains only one fourth part of the area, or ſurface of *B*. For, all circles, as well as ſquare ſurfaces, are to one another, as the ſquares of their diameters. Thus, the ſquare *A* is juſt half as broad as the ſquare *B*; and yet it is plain to ſight, that *B* contains four times as much ſurface as *A*. Hence, by comparing the diameters of the above Circles (Fig. II.) together, it will be found, that in round numbers, the Sun appears 7 times larger to Mercury than to us, 90 times larger to us than to Saturn, and 630 times as large to Mercury as to Saturn. Fig. III. Fig. IV.

88. In Fig. 5th, we have a view of the bulks of the Planets in proportion to each other, and to a ſuppoſed globe of two feet diameter for the Sun. The Earth is 27 times as big as Mercury, very little bigger than Venus, 5 times as big as Mars; but Jupiter is 1049 times as big as the Earth, Saturn 586 times as big, excluſive of his Ring; and the Sun is 877 thouſand 650 times as big as the Earth. If the Planets in this Figure were ſet at their due diſtances from a Sun of two feet diameter, Fig. V. Proportional bulks and diſtances of the Planets.

 according

PLATE I. according to their proportional bulks, as in our Syſtem, Mercury would be 28 yards from the Sun's center; Venus 51 yards 1 foot; the Earth 70 yards 2 feet; Mars 107 yards 2 feet; Jupiter 370 yards 2 feet; and Saturn 760 yards 2 feet. The Comet of the year 1680, at it's greateſt diſtance, 10 thouſand 760 yards. In this proportion, the Moon's diſtance from the center of the Earth would be only $7\frac{1}{2}$ inches.

An idea of their diſtances.

89. To aſſiſt the imagination in forming an idea of the vaſt diſtances of the Sun, Planets, and Stars, let us ſuppoſe, that a body projected from the Sun ſhould continue to fly with the ſwiftneſs of a cannon-ball; *i. e.* 480 miles every hour; this body would reach the Orbit of Mercury, in 7 years 221 days; of Venus, in 14 years 8 days; of the Earth, in 19 years 91 days; of Mars, in 29 years 85 days; of Jupiter, in 100 years 280 days; of Saturn, in 184 years 240 days; to the Comet of 1680, at it's greateſt diſtance from the Sun, in 2660 years; and to the neareſt fixed Stars in about 7 million 600 thouſand years.

Why the Planets appear bigger and leſs at different times.

90. As the Earth is not the center of the Orbits in which the Planets move, they come nearer to it and go farther from it, and at different times; on which account they appear bigger and leſs by turns. Hence, the apparent magnitudes of the Planets are not always a certain rule to know them by.

91. Under Fig. 3, are the names and characters of the twelve Signs of the Zodiac, which the Reader ſhould be perfectly well acquainted with; ſo as to know the characters without ſeeing the names. Every Sign contains 30 degrees, as in the Circle bounding the Solar Syſtem; to which the characters of the Signs are ſet in their proper places. Fig. I.

The Comets.

92. The COMETS are ſolid opaque bodies, with long tranſparent trains or tails, iſſuing from that ſide which is turned away from the Sun. They move about the Sun, in very excentric ellipſes; and are

are of a much greater density than the Earth; for some of them are heated in every period to such a degree, as would vitrify or dissipate any substance known to us. Sir ISAAC NEWTON computed the heat of the Comet which appeared in the year 1680, when nearest the Sun, to be 2000 times hotter than red-hot iron, and that being thus heated, it must retain it's heat until it comes round again, although it's Period should be more than twenty thousand years; and it is computed to be only 575. The method of computing the heat of bodies, keeping at any known distance from the Sun, so far as their heat depends on the force of the Sun's rays, is very easy; and shall be explained in the eighth Chapter. PLATE I.

93. Part of the Paths of three Comets are delineated in the Scheme of the Solar System, and the years marked in which they made their appearance. It is believed, that there are at least 21 Comets belonging to our System, moving in all sorts of directions: and all those which have been observed, have moved through the ethereal Regions and the Orbits of the Plane s without suffering the least sensible resistance in their motions; which plainly proves that the Planets do not move in solid Orbs. Of all the Comets, the Periods of the above-mentioned three only are known with any degree of certainty. The first of these Comets appeared in the years 1531, 1607, and 1682; and is expected to appear again in the year 1758, and every 75th year afterwards. The second of them appeared in 1532 and 1661, and may be expected to return in 1789, and every 129th year afterwards. The third, having last appeared in 1680, and it's Period being no less than 575 years, cannot return until the year 2225. This Comet, at it's greatest distance, is about 11 thousand two hundred millions of miles from the Sun; and at it's least distance from the Sun's center, which is 49,000 miles, is within less than a thirt part of the Sun's semidiameter from his

Fig. I.

They prove that the Orbits of the Planets are not solid.

The Periods only of three are known.

his ſurface. In that part of it's Orbit which is neareſt the Sun, it flies with the amazing ſwiftneſs of 880,000 miles in an hour; and the Sun, as ſeen from it, appears an hundred degrees in breadth; conſequently, 40 thouſand times as large as he appears to us. The aſtoniſhing length that this Comet runs out into empty Space, ſuggeſts to our minds an idea of the vaſt diſtance between the Sun and the neareſt fixed Stars; of whoſe Attractions all the Comets muſt keep clear, to return periodically, and go round the Sun; and it ſhews us alſo, that the neareſt Stars, which are probably thoſe that ſeem the largeſt, are as big as our Sun, and of the ſame nature with him; otherwiſe, they could not appear ſo large and bright to us as they do at ſuch an immenſe diſtance.

They prove the Stars to be at immenſe diſtances.

Inferences drawn from the above phenomena.

94. The extreme heat, the denſe atmoſphere, the groſs vapours, the chaotic ſtate of the Comets, ſeem at firſt ſight to indicate them altogether unfit for the purpoſes of animal life, and a moſt miſerable habitation for rational beings; and therefore * ſome are of opinion that they are ſo many hells for tormenting the damned with perpetual viciſſitudes of heat and cold. But when we conſider, on the other hand, the infinite power and goodneſs of the Deity; the latter inclining, the former enabling him to make creatures ſuited to all ſtates and circumſtances; that matter exiſts only for the ſake of intelligent beings; and that wherever we find it, we always find it pregnant with life, or neceſſarily ſubſervient thereto; the numberleſs ſpecies, the aſtoniſhing diverſity of animals in earth, air, water, and even on other animals; every blade of graſs, every tender leaf, every natural fluid, ſwarming with life; and every one of theſe enjoying ſuch gratifications as the nature and ſtate of each requires: when we reflect moreover that ſome centuries ago, till experience undeceived us, a great part of the Earth was judged uninhabitable; the Torid

* Mr. WHISTON, in his Aſtronomical Principles of Religion.

Zone

Zone by reaſon of exceſſive heat, and the two Frigid Zones becauſe of their intolerable cold; it ſeems highly probable, that ſuch numerous and large maſſes of durable matter as the Comets are, however unlike they be to our Earth, are not deſtitute of beings capable of contemplating with wonder, and acknowledging with gratitude, the wiſdom, ſymmetry, and beauty of the Creation; which is more plainly to be obſerved in their extenſive Tour through the Heavens, than in our more confined Circuit. If farther conjecture is permitted, may we not ſuppoſe them inſtrumental in recruiting the expended fuel of the Sun; and ſupplying the exhauſted moiſture of the Planets? However difficult it may be, circumſtanced as we are, to find out their particular deſtination, this is an undoubted truth, that wherever the Deity exerts his power, there he alſo manifeſts his wiſdom and goodneſs.

95. THE SOLAR SYSTEM here deſcribed is not a late invention; for it was known and taught by the wiſe *Samian* philoſopher PYTHAGORAS, and others among the ancients; but in latter times was loſt, 'till the 15th century, when it was again reſtored by the famous *Poliſh* philoſopher, NICHOLAUS COPERNICUS, who was born at *Thorn* in the year 1473. In this, he was followed by the greateſt mathematicians and philoſophers that have ſince lived; as KEPLER, GALILEO, DESCARTES, GASSENDUS, and Sir ISAAC NEWTON; the laſt of whom has eſtabliſhed this Syſtem on ſuch an everlaſting foundation of mathematical and phyſical demonſtration, as can never be ſhaken: and none who underſtand him can heſitate about it.

This Syſtem very ancient, and demonſtrable.

96. In the *Ptolemean Syſtem* the Earth was ſuppoſed to be fixed in the Center of the Univerſe; and that the Moon, Mercury, Venus, the Sun, Mars, Jupiter, and Saturn, moved round the Earth: above the Planets, this Hypotheſis placed the Firmament of Stars, and then the two Cryſtalline

The Ptolemean Syſtem abſurd.

Spheres; all which were included in and received motion from the *Primum Mobile*, which constantly revolved about the Earth in 24 hours from East to West. But as this rude Scheme was found incapable to stand the test of art and observation, it was soon rejected by all true philosophers; notwithstanding the opposition and violence of blind and zealous bigots.

The Tychonic System, partly true and partly false.

97. The *Tychonic System* succeeded the *Ptolemean*, but was never so generally received. In this the Earth was supposed to stand still in the Center of the Universe or Firmament of Stars, and the Sun to revolve about it every 24 hours; the Planets, Mercury, Venus, Mars, Jupiter, and Saturn, going round the Sun in the times already mentioned. But some of TYCHO's disciples supposed the Earth to have a diurnal motion round it's Axis, and the Sun with all the above Planets to go round the Earth in a year; the Planets moving round the Sun in the foresaid times. This hypothesis, being partly true and partly false, was embraced by few; and soon gave way to the only true and rational System, restored by COPERNICUS and demonstrated by Sir ISAAC NEWTON.

98. To bring the foregoing particulars at once in view, with several others which follow, concerning the Periods, Distances, Bulks, &c. of the Planets, the following Table is inserted.

A TABLE

A TABLE of the PERIODS, REVOLUTIONS, MAGNITUDES, &c. of the PLANETS, as formerly computed by Aſtronomers.——For their true Diſtances of the SUN, as lately determined from Obſervations of the Tranſit of Venus, *See* § 194.

SUN and Planets.	Annual period round the Sun.	Diurnal rotation on it's Axis.	Diameter in Engliſh miles.	Mean diam. as ſeen fr. the Sun.	Mean diſtance from the Sun in Engliſh miles	Excentricity of it's Orbit in miles.	Axis inclined to Orbit.	Orbit inclined to Ecliptic.	Place of it's Aphelion.	Place of it's Aſcending Node.	Proportion of Diameters	Proportion of Bulk	Prop. of Gravity on the ſurface	Proportion of Denſity.
SUN	——	25 d. 6 h.	763000	——	——	——	8° 0′	——	——	——	10000	877650	24	$25\frac{1}{2}$
Mercury	87ᵈ 23ʰ	Unknown.	2600	20″	32,000,000	6,720,000	Unkn.	6° 54′	♐ 13° 8′	♉ 14° 43′	$34\frac{1}{10}$	$\frac{1}{27}$	Unkn.	Unkn.
Venus	224ᵈ 17ʰ	24 d. 8 h.	7906	30″	59,000,000	413,000	75° 0′	3° 20′	♒ 4° 20′	♊ 13° 59′	$103\frac{1}{2}$	1	Unkn.	Unkn.
Earth	365ᵈ 6ʰ	1 d. 0 h.	7970	21″	82,000,000	1,377,000	23° 29′	0° 0′	♑ 8° 1′	——	$104\frac{1}{2}$	1	1	100
Moon	365ᵈ 6ʰ	29 d. $12\frac{3}{4}$ h.	2180	6″	82,000,000	13,000	2° 10′	5° 18′	——	Variable.	$28\frac{1}{2}$	$\frac{1}{50}$	$\frac{34}{100}$	$123\frac{1}{2}$
Mars	686ᵈ 23ʰ	24 h. 40 m.	4444	11″	125,000,000	11,439,000	0° 0′	1° 52′	♍ 0° 32′	♉ 17° 17′	$58\frac{1}{5}$	$\frac{1}{5}$	Unkn.	Unkn.
Jupiter	4332ᵈ 12ʰ	9 h. 56 m.	81000	37″	426,000,000	20,352,000	0° 0′	1° 20′	♎ 9° 10′	♋ 7° 29′	$1061\frac{2}{3}$	1049	2	19
Saturn	10759ᵈ 7ʰ	Unknown.	67000	16″	780,000,000	42,735,000	Unkn.	2° 30′	♐ 27° 50′	♋ 21° 13′	$878\frac{1}{9}$	586	$1\frac{1}{2}$	15

SUN and Planets.	Proportion of Light & Heat.	Propor. quantity of Matter.	Hourly motion in it's Orbit.	Hourly motion of it's Equator	Square miles in ſurface.	Cubic miles in ſolidity.	Would fall to the Sun in (days h.) — If the projectile force was deſtroyed.
SUN	45000	227500	——	3818	1,828,911,000,000	232,577,115,137,000,000	
Mercury	$6\frac{1}{2}$	Unkn.	95000	Unkn.	21,236,800	9,195,534,500	15 13
Venus	$1\frac{3}{4}$	Unkn.	69000	43	691,361,300	258,507,832,200	39 17
Earth	1	1	58000	1042	199,852,860	265,404,598,080	64 10
Moon	1 ±	$\frac{1}{40}$	2290	$9\frac{1}{2}$	14,898,750	5,408,246,000	64 10
Mars	$\frac{3}{7}$	Unkn.	47000	556	62,038,240	45,969,335,840	121 0
Jupiter	$\frac{1}{28}$	220	25000	25920	20,603,970,000	278,153,595,000,000	290 0
Saturn	$\frac{1}{90}$	94	18000	Unkn.	14,102,562,000	155,128,182,000,000	767 0

Jupiter's Moons. Nº	Periods round Jupiter. D.	H.	M
1	1	18	36
2	3	13	15
3	7	3	59
4	16	18	30

If the Moon's projectile force was deſtroyed, ſhe would fall to the Earth in 4 days 21 hours.

Saturn's Moons. Nº	Periods round Saturn. D.	H.	M.
1	1	21	19
2	2	17	40
3	4	12	25
4	15	22	41
5	79	7	48

CHAP. III.

The COPERNICAN SYSTEM *demonstrated to be true.*

Of matter and motion.

99. MATTER is of itfelf inactive, and indifferent to motion or reft. A body at reft can never put itfelf in motion; a body in motion can never ftop or move flower of itfelf. Hence, when we fee a body in motion, we conclude fome other fubftance muft have given it that motion; when we fee a body fall from motion to reft, we conclude fome other body or caufe ftopt it.

100. All motion is naturally rectilineal. A bullet thrown by the hand, or difcharged from a cannon, would continue to move in the fame direction it received at firft, if no other power diverted it's courfe. Therefore, when we fee a body moving in a curve of whatever kind, we conclude it muft be acted upon by two powers at leaft: one to put it in motion, and another drawing it off from the rectilineal courfe which it would otherwife have continued to move in.

Gravity demonftrable.

101. The power by which bodies fall towards the Earth, is called *Gravity* or *Attraction*. By this power in the Earth it is, that all bodies, on whatever fide, fall in lines perpendicular to it's furface. On oppofite parts of the Earth bodies fall in oppofite directions, all towards the center, where the whole force of gravity is as it were accumulated. By this power conftantly acting on bodies near the Earth they are kept from leaving it altogether; and thofe on it's furface are kept thereto on all fides, fo that they cannot fall from it. Bodies thrown with any obliquity are drawn by this power from a ftraight line into a curve, until they fall to the ground: the greater the force by which they are thrown, the greater is the diftance they are carried before they fall. If we fuppofe a body carried

feveral

ſeveral miles above the Earth, and there projected in an horizontal direction with ſo great a velocity, that it would move more than a ſemidiameter of the Earth, in the time it would take to fall to the Earth by gravity; in that caſe, if there were no reſiſting medium in the way, the body would not fall to the Earth at all, but continue to circulate round the Earth, keeping always the ſame path, and returning to the point from whence it was projected with the ſame velocity as at firſt.

102. We find the Moon moves round the Earth in an Orbit nearly circular. The Moon therefore muſt be acted on by two powers or forces; one which would cauſe her to move in a right line, another bending her motion from that line into a curve. This attractive power muſt be ſeated in the Earth; for there is no other body within the Moon's Orbit to draw her. The attractive power of the Earth therefore extends to the Moon; and, in combination with her projectile force, cauſes her to move round the Earth in the ſame manner as the circulating body above ſuppoſed. Projectile force demonſtrable.

103. The Moons of Jupiter and Saturn are obſerved to move round their primary Planets: therefore there is ſuch a power as gravity in theſe Planets. All the Planets move round the Sun, and reſpect it for their center of motion: therefore the Sun muſt be endowed with an attracting force, as well as the Earth and Planets. The like may be proved of the Comets. So that all the bodies or matter of the Solar Syſtem are poſſeſſed of this power; and perhaps ſo is all matter whatſoever. The Sun and Planets attract each other.

104. As the Sun attracts the Planets with their Satellites, and the Earth the Moon, ſo the Planets and Satellites re-attract the Sun, and the Moon the Earth: action and re-action being always equal. This is alſo confirmed by obſervation; for the Moon raiſes tides in the ocean, the Satellites and Planets diſturb one another's motions.

105. Every

105. Every particle of matter being poſſeſſed of an attracting power, the effect of the whole muſt be in proportion to the number of attracting particles; that is, to the quantity of matter in the body. This is demonſtrated from experiments on pendulums: for, if they are of equal lengths, whatever their weights be, they always vibrate in equal times. Now, if one be double the weight of another, the force of gravity or attraction muſt be double to make it oſcillate with the ſame celerity: if one is thrice the weight or quantity of matter of another, it requires thrice the force of gravity to make it move with the ſame celerity. Hence it is certain, that the power of gravity is always porportional to the quantity of matter in bodies, whatever their bulks or figures are.

106. Gravity alſo, like all other virtues or emanations, either drawing or impelling a body towards a center, decreaſes as the ſquare of the diſtance increaſes: that is, a body at twice the diſtance attracts another with only a fourth part of the force; at four times the diſtance, with a ſixteenth part of the force. This too is confirmed from obſervation, by comparing the diſtance which the Moon falls in a minute from a right line touching her Orbit, with the ſpace which bodies near the Earth fall in the ſame time: and alſo by comparing the forces which retain Jupiter's Moons in their Orbits. This will be more fully explained in the ſeventh Chapter.

Gravitation and projection exemplified.

107. The mutual attraction of bodies may be exemplified by a boat and a ſhip on the Water, tied by a rope. Let a man either in a ſhip or boat pull the rope (it is the ſame in effect at which end he pulls, for the rope will be equally ſtretched throughout) the ſhip and boat will be drawn towards one another; but with this difference, that the boat will move as much faſter than the ſhip, as the ſhip is heavier than the boat. Suppoſe the boat as heavy as the ſhip, and they will draw one another

another equally (setting aside the greater resistance of the Water on the bigger body) and meet in the middle of the first distance between them. If the ship is a thousand or ten thousand times heavier than the boat, the boat will be drawn a thousand or ten thousand times faster than the ship; and meet proportionably nearer the place from which the ship set out. Now, whilst one man pulls the rope, endeavouring to bring the ship and boat together, let another man, in the boat, endeavour to row it off sidewise, or at right Angles to the rope; and the former, instead of being able to draw the boat to the ship, will find it enough for him to keep the boat from going further off; whilst the latter, endeavouring to row off the boat in a straight line, will, by means of the other's pulling it towards the ship, row the boat round the ship at the rope's length from her. Here, the power employed to draw the ship and boat to one another represents the mutual attraction of the Sun and Planets, by which the Planets would fall freely towards the Sun with a quick motion; and would also in falling attract the Sun towards them. And the power employed to row off the boat represents the projectile force impressed on the Planets at right angles, or nearly so, to the Sun's attraction; by which means the Planets move round the Sun, and are kept from falling to it. On the other hand, if it be attempted to make a heavy ship go round a light boat, they will meet sooner than the ship can get round; or the ship will drag the boat after it.

108. Let the above principles be applied to the Sun and Earth; and they will evince, beyond a possibility of doubt, that the Sun, not the Earth, is the center of the System; and that the Earth moves round the Sun as the other Planets do.

For, if the Sun moves about the Earth, the Earth's attractive power must draw the Sun towards it from the line of projection so, as to bend it's motion

motion into a curve. But the Sun being at leaſt 227 thouſand times as heavy as the Earth, by being ſo much weightier as it's quantity of matter is greater, it muſt move 227 thouſand times as ſlowly toward the Earth, as the Earth does toward the Sun; and conſequently the Earth would fall to the Sun in a ſhort time, if it had not a very ſtrong projectile motion to carry it off. The Earth therefore, as well as every other Planet in the Syſtem, muſt have a rectilineal impulſe, to prevent it's falling into the Sun. To ſay, that gravitation retains all the other Planets in their Orbits without affecting the Earth, which is placed between the Orbits of Mars and Venus, is as abſurd as to ſuppoſe that ſix cannon-bullets might be projected upwards to different heights in the Air, and that five of them ſhould fall down to the ground; but the ſixth, which is neither the higheſt nor the loweſt, ſhould remain ſuſpended in the Air without falling, and the Earth move round about it.

The abſurdity of ſuppoſing the Earth at reſt.

109. There is no ſuch thing in nature as a heavy body moving round a light one as it's center of motion. A pebble faſtened to a mill-ſtone by a ſtring, may by an eaſy impulſe be made to circulate round the mill-ſtone: but no impulſe can make a mill-ſtone circulate round a looſe pebble, for the heavieſt would undoubtedly carry the lighteſt along with it wherever it goes.

110. The Sun is ſo immenſely bigger and heavier than the Earth *, that if he was moved out of his place, not only the Earth, but all the other Planets, if they were united into one maſs, would be carried along with the Sun, as the pebble would be with the mill-ſtone.

111. By conſidering the law of gravitation, which takes place throughout the Solar Syſtem, in another light, it will be evident that the Earth moves round the Sun in a year; and not the Sun round the Earth. It has been ſhewn (§ 106) that

* As will be demonſtrated in the ninth Chapter.

the

the power of gravity decreafes as the fquare of the diftance increafes: and from this it follows with mathematical certainty, that when two or more bodies move round another as their center of motion, the fquares of their periodic times will be to one another in the fame proportion, as the cubes of their diftances from the central body. This holds precifely with regard to the Planets round the Sun, and the Satellites round the Planets; the relative diftances of all which, are well known. But, if we fuppofe the Sun to move round the Earth, and compare it's period with the Moon's by the above rule, it will be found that the Sun would take no lefs than 173,510 days to move round the Earth, in which cafe our year would be 475 times as long as it now is. To this we may add, that the afpects of increafe and decreafe of the Planets, the times of their feeming to ftand ftill, and to move direct and retrograde, anfwer precifely to the Earth's motion; but not at all to the Sun's, without introducing the moft abfurd and monftrous fuppofitions, which would deftroy all harmony, order, and fimplicity in the Syftem. Moreover, if the Earth is fuppofed to ftand ftill, and the Stars to revolve in free fpaces about the Earth in 24 hours, it is certain that the forces by which the Stars revolve in their Orbits are not directed to the Earth, but to the centers of the feveral Orbits; that is, of the feveral parallel Circles which the Stars on different fides of the equator defcribe every day: and the like inferences may be drawn from the fuppofed diurnal motion of the Planets, fince they are never in the Equinoctial but twice, in their courfes with regard to the ftarry Heavens. But, that forces fhould be directed to no central body, on which they phyfically depend, but to innumerable imaginary points in the Axe of the Earth produced to the Poles of the Heavens, is an hypothefis too abfurd to be allowed of by any rational creature. And it is ftill more abfurd

The harmony of the celeftial motions.

The abfurdity of fuppofing the Stars and Planets to move round the Earth.

ſurd to imagine that theſe forces ſhould increaſe exactly in proportion to the diſtances from this Axe; for this is an indication of an increaſe to infinity; whereas the force of attraction is found to decreaſe in receding from the fountain from whence it flows. But, the farther any Star is from the quieſcent Pole, the greater muſt be the Orbit which it deſcribes; and yet it appears to go round in the ſame time as the neareſt Star to the Pole does. And if we take into conſideration the two-fold motion obſerved in the Stars, one diurnal round the Axis of the Earth in 24 hours, and the other round the Axis of the Ecliptic in 25920 years, § 251, it would require an explication of ſuch a perplexed compoſition of forces, as could by no means be reconciled with any phyſical Theory.

Objections againſt the Earth's motion anſwered.

112. There is but one objection of any weight that can be made againſt the Earth's motion round the Sun; which is, that in oppoſite points of the Earth's Orbit, it's Axis, which always keeps a parallel direction, would point to different fixed Stars; which is not found to be fact. But this objection is eaſily removed, by conſidering the immenſe diſtance of the Stars in reſpect of the diameter of the Earth's Orbit; the latter being no more than a point when compared to the former. If we lay a ruler on the ſide of a table, and along the edge of the ruler view the top of a ſpire at ten miles diſtance; then lay the ruler on the oppoſite ſide of the table in a parallel ſituation to what it had before, and the ſpire will ſtill appear along the edge of the ruler; becauſe our eyes, even when aſſiſted by the beſt inſtruments, are incapable of diſtinguiſhing ſo ſmall a change at ſo great a diſtance.

113. Dr. BRADLEY, our preſent Aſtronomer Royal, has found by a long ſeries of the moſt accurate obſervations, that there is a ſmall apparent motion of the fixed Stars, occaſioned by the aberration of their light, and ſo exactly anſwering to an

an annual motion of the Earth, as evinces the same, even to a mathematical demonstration. Those who are qualified to read the Doctor's modest Account of this great discovery, may consult the *Philosophical Transactions*, N° 406. Or they may find it treated of at large by Drs. SMITH *, LONG †, DESAGULIERS ‡, RUTHERFURTH ||, Mr. MACLAURIN, and M. DE LA CAILLE **.

114. It is true that the Sun seems to change his place daily, so as to make a tour round the starry Heavens in a year. But whether the Sun or Earth moves, this appearance will be the same; for, when the Earth is in any part of the Heavens, the Sun will appear in the opposite. And therefore, this appearance can be no objection against the motion of the Earth. Why the Sun appears to change his place.

115. It is well known to every person who has sailed on smooth Water, or been carried by a stream in a calm, that however fast the vessel goes, he does not feel it's progressive motion. The motion of the Earth is incomparably more smooth and uniform than that of a ship, or any machine made and moved by human art: and therefore it is not to be imagined that we can feel it's motion.

116. We find that the Sun, and those Planets on which there are visible spots, turn round their Axes: for the spots move regularly over their Disks ††. From hence we may reasonably conclude that the other Planets, on which we see no spots, and the Earth, which is likewise a Planet, have such rotations. But being incapable of leaving the Earth, and viewing it at a distance, and it's rotation being smooth and uniform, we can neither The Earth's motion on it's Axis demonstrated.

* Optics, B. I. § 1178. † Astronomy, B. II. § 838.

‡ Philosophy, Vol. I. p. 401. || Account of Sir Isaac Newton's *Philosophical Discoveries*, B. III. c. 2. § 3.

** *Elements d'Astronomie*, § 381.

†† The face of the Sun, Moon, or any Planet, as it appears to the eye, is called it's Disk.

ſee it move on it's Axis as we do the Planets, nor feel ourſelves affected by it's motion. Yet there is one effect of ſuch a motion, which will enable us to judge with certainty whether the Earth revolves on it's Axis or not. All Globes which do not turn round their Axes will be perfect ſpheres, on account of the equality of the weight of bodies on their ſurfaces; eſpecially of the fluid parts. But all Globes which turn on their Axes will be oblate ſpheroids; that is, their ſurfaces will be higher, or farther from the center, in the equatoreal than in the polar Regions: for, as the equatoreal parts move quickeſt, they will recede farther from the Axis of motion, and enlarge the equatoreal diameter. That our Earth is really of this figure, is demonſtrable from the unequal vibrations of a pendulum, and the unequal lengths of degrees in different latitudes. Since then the Earth is higher at the Equator than at the Poles, the ſea, which naturally runs downward, or towards the places which are neareſt the center, would run towards the polar Regions, and leave the equatoreal parts dry, if the centrifugal force of theſe parts, by which the waters were carried thither, did not keep them from returning. The Earth's equatoreal diameter is 35 miles longer than it's Axis.

All bodies heavier at the Poles than they would be at the Equator.

117. Bodies near the Poles are heavier than thoſe towards the Equator, becauſe they are nearer the Earth's center, where the whole force of the Earth's attraction is accumulated They are alſo heavier, becauſe their centrifugal force is leſs, on account of their diurnal motion being ſlower. For both theſe reaſons, bodies carried from the Poles toward the Equator, gradually loſe of their weight. Experiments prove that a pendulum, which vibrates ſeconds near the Poles, vibrates ſlower near the Equator, which ſhews that it is lighter or leſs attracted there. To make it oſcillate in the ſame time, it is found neceſſary to diminiſh it's length. By comparing the different lengths of pendulums ſwinging

swinging seconds at the Equator and at *London*, it is found that a pendulum must be $2\frac{169}{1000}$ lines shorter at the Equator than at the Poles. A line is a twelfth part of an inch.

118. If the Earth turned round it's Axis in 84 minutes 43 seconds, the centrifugal force would be equal to the power of gravity at the Equator; and all bodies there would entirely lose their weight. If the Earth revolved quicker, they would all fly off, and leave it. How they might lose all their weight.

119. One on the Earth can no more be sensible of it's undisturbed motion on it's Axis, than one in the cabbin of a ship on smooth water can be sensible of her motion when she turns gently and uniformly round. It is therefore no argument against the Earth's diurnal motion that we do not feel it: nor is the apparent revolutions of the celestial bodies every day a proof of the reality of these motions; for whether we or they revolve, the appearance is the very same. A person looking through the cabbin-windows of a ship as strongly fancies the objects on land to go round when the ship turns, as if they were actually in motion. The Earth's motion cannot be felt.

120. If we could translate ourselves from Planet to Planet, we should still find that the Stars would appear of the same magnitudes, and at the same distances from each other, as they do to us here; because the width of the remotest Planet's Orbit bears no sensible proportion to the distance of the Stars. But then, the Heavens would seem to revolve about very different Axes; and consequently, those quiescent points, which are our Poles in the Heavens, would seem to revolve about other points, which, though apparently in motion as seen from the Earth, would be at rest as seen from any other Planet. Thus the Axis of Venus, which lies almost at right Angles to the Axis of the Earth, would have it's motionless Poles in two opposite points of the Heavens lying almost in our Equi- To the different Planets the Heavens appear to turn round on different Axes.

 noctial,

noctial, where the motion appears quickeſt, becauſe it is ſeemingly performed in the greateſt Circle. And the very Poles, which are at reſt to us, have the quickeſt motion of all as ſeen from Venus. To Mars and Jupiter the Heavens appear to turn round with very different velocities on the ſame Axis, whoſe Poles are about 23½ degrees from ours. Were we on Jupiter, we ſhould be at firſt amazed at the rapid motion of the Heavens; the Sun and Stars going round in 9 hours 56 minutes. Could we go from thence to Venus, we ſhould be as much ſurpriſed at the ſlowneſs of the heavenly motions; the Sun going but once round in 584 hours, and the Stars in 540. And could we go from Venus to the Moon, we ſhould ſee the Heavens turn round with a yet ſlower motion; the Sun in 708 hours, the Stars in 655. As it is impoſſible theſe various circumvolutions in ſuch different times, and on ſuch different Axes, can be real, ſo it is unreaſonable to ſuppoſe the Heavens to revolve about our Earth more than it does about any other Planet. When we reflect on the vaſt diſtance of the fixed Stars, to which 162,000,000 of miles, the diameter of the Earth's Orbit, is but a point, we are filled with amazement at the immenſity of their diſtance. But if we try to frame an idea of the extreme rapidity with which the Stars muſt move, if they move round the Earth in 24 hours, the thought becomes ſo much too big for our imagination, that we can no more conceive it than we do infinity or eternity. If the Sun was to go round the Earth in 24 hours, he muſt travel upwards of 300,000 miles in a minute: but the Stars being at leaſt 400,000 times as far from the Sun, as the Sun is from us, thoſe about the Equator muſt move 400,000 times as quick. And all this to ſerve no other purpoſe than what can be as fully and much more ſimply obtained by the Earth's turning round eaſtward, as on an Axis, every 24 hours, cauſing thereby an apparent

rent diurnal motion of the Sun weſtward, and bringing about the alternate returns of day and night.

121. As to the common objections againſt the Earth's motion on it's Axis, they are all eaſily anſwered and ſet aſide. That it may turn without being ſeen or felt by us to do ſo, has been already ſhewn, § 119. But ſome are apt to imagine that if the Earth turns eaſtward (as it certainly does if it turns at all) a ball fired perpendicularly upward in the air muſt fall conſiderably weſtward of the place it was projected from. The objection, which at firſt ſeems to have ſome weight, will be found to have none at all, when we conſider that the gun and ball partake of the Earth's motion; and therefore the ball being carried forward with the air as quick as the Earth and air turn, muſt fall down on the ſame place. A ſtone let fall from the top of a main-maſt, if it meets with no obſtacle, falls on the deck as near the foot of the maſt when the ſhip ſails as when it does not. If an inverted bottle, full of liquor, be hung up to the ceiling of the cabbin, and a ſmall hole be made in the cork to let the liquor drop through on the floor, the drops will fall juſt as far forward on the floor when the ſhip ſails as when it is at reſt. And gnats or flies can as eaſily dance among one another in a moving cabbin as in a fixed chamber. As for thoſe ſcripture expreſſions which ſeem to contradict the Earth's motion, this general anſwer may be made to them all, *viz.* it is plain from many inſtances that the Scriptures were never intended to inſtruct us in Philoſophy or Aſtronomy; and therefore, on thoſe ſubjects, expreſſions are not always to be taken in the ſtricteſt ſenſe; but for the moſt part as accommodated to the common apprehenſions of mankind. Men of ſenſe in all ages, when not treating of the ſciences purpoſely, have followed this method: and it would be in vain to follow any other in addreſſing ourſelves to the vulgar, or bulk of

Objections againſt the Earth's diurnal motion anſwered.

any community. *Moſes* calls the Moon A GREAT LUMINARY (as it is in the Hebrew) as well as the Sun: but the Moon is known to be an opaque body, and the ſmalleſt that Aſtronomers have obſerved in the Heavens; and ſhines upon us not by any inherent light of it's own, but by reflecting the light of the Sun. If *Moſes* had known this, and told the *Iſraelites* ſo, they would have ſtared at him; and conſidered him rather as a madman than as a perſon commiſſioned by the Almighty to be their leader.

CHAP. IV.

The Phenomena of the Heavens as ſeen from different parts of the Earth.

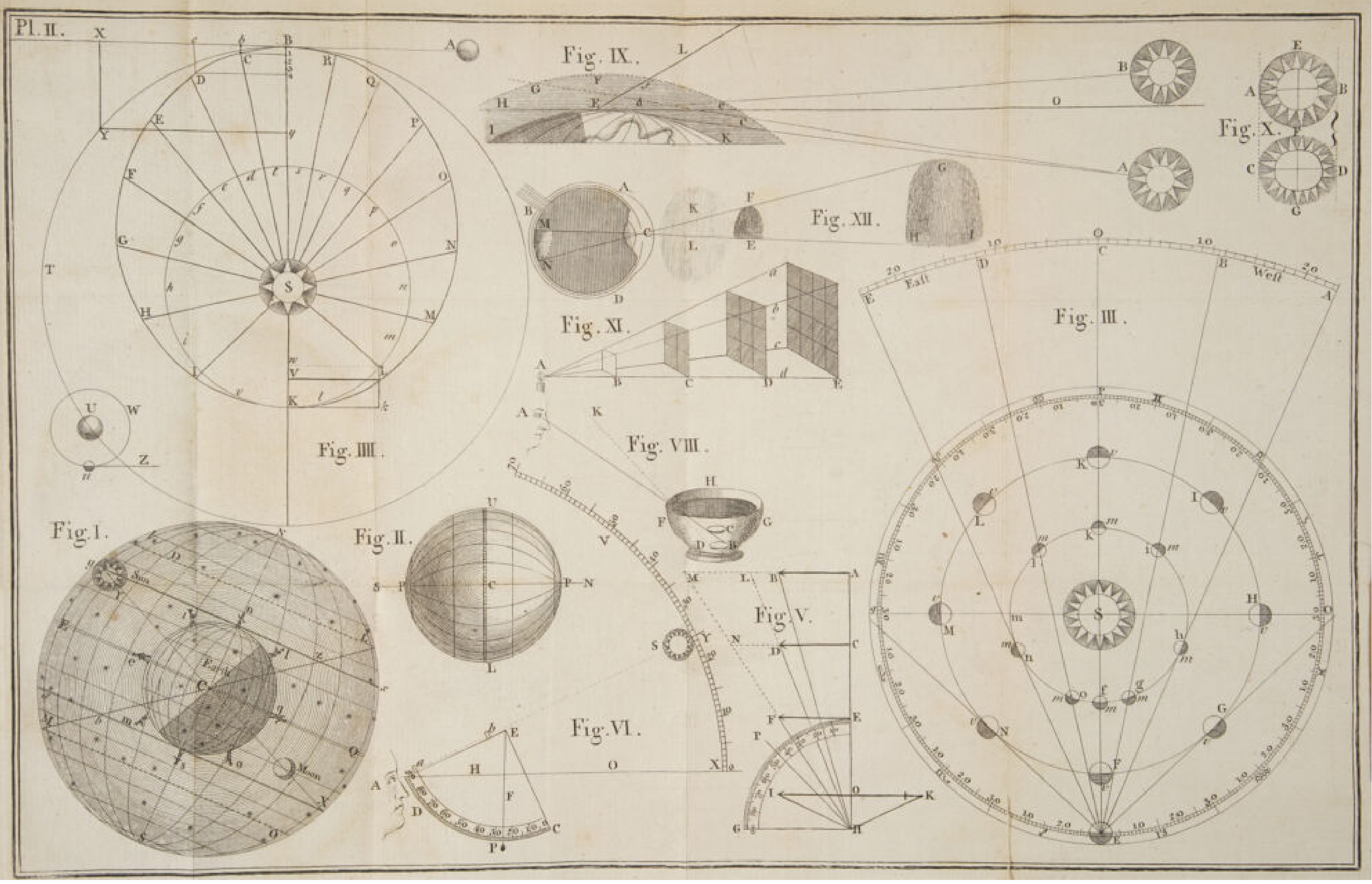
We are kept to the Earth by gravity.

122. WE are kept to the Earth's ſurface on all ſides by the power of it's central attraction; which, laying hold of all bodies according to their denſities or quantities of matter without regard to their bulks, conſtitutes what we call their *weight*. And having the ſky over our heads, go where we will, and our feet towards the center of the Earth, we call it *up* over our heads, and *down* under our feet: although the ſame right line which is *down* to us, if continued through and beyond the oppoſite ſide of the Earth, would be *up* to the inhabitants on the oppoſite ſide. For, the inhabitants *n*, *i*, *e*, *m*, *s*, *o*, *q*, *l* ſtand with their feet toward the Earth's center *C*; and have the ſame figure of ſky *N*, *I*, *E*, *M*, *S*, *O*, *Q*, *L* over their heads. Therefore, the point *S* is as directly upward to the inhabitant *s* on the South Pole, as *N* is to the inhabitant *n* on the North Pole: ſo is *E* to the inhabitant *e*, ſuppoſed to be on the north end of *Peru*; and *Q* to the oppoſite inhabitant *q* on the middle of the iſland *Sumatra*. Each of theſe obſervers is ſurpriſed that his oppoſite or *Antipode* can ſtand with his head hanging downwards. But let either

PLATE II. Fig. I.

Antipodes.

go



Pl. II.
Fig. I.
Sun
Earth
Moon
Fig. II.
Fig. III.
East
West
Fig. IIII.
Fig. V.
Fig. VI.
Fig. VIII.
Fig. IX.
Fig. X.
Fig. XI.
Fig. XII.

PLATE II. attraction; and therefore it has no such thing as an upper and an under side: for all bodies on or near it's surface, even to the Moon, gravitate towards it's center.

124. Let any man imagine that the Earth and every thing but himself is taken away, and he left alone in the midst of indefinite Space; he could then have no idea of *up* or *down*; and were his pockets full of gold, he might take the pieces one by one, and throw them away on all sides of him, without any danger of losing them; for the attraction of his body would bring them all back by the ways they went, and *he* would be *down* to every one of them. But then, if a Sun or any other large body were created, and placed in any part of Space several millions of miles from him, he would be attracted towards it, and could not save himself from falling *down* to it.

Fig. I. 125. The Earth's bulk is but a point, as that at *C*, compared to the Heavens; and therefore every inhabitant upon it, let him be where he will, as at *n*, *e*, *m*, *s*, &c. sees half of the Heavens. The inhabitant *n*, on the North Pole of the Earth, constantly sees the Hemisphere *ENQ*; and having the North Pole *N* of the Heavens just over his head, his * Horizon coincides with the Celestial Equator *ECQ*. Therefore all the Stars in the Northern Hemisphere *ENQ*, between the Equator and North Pole, appear to turn round the line *NC*, moving parallel to the Horizon. The Equatoreal Stars keep in the Horizon, and all those in the Southern Hemisphere *ESQ* are invisible. The like Phenomena are seen by the observer *s* on the South Pole, with respect to the Hemisphere *ESQ*; and to him the opposite Hemisphere is always invisible. Hence, under either Pole, only one

One half of the Heavens visible to an inhabitant on any part of the Earth.

* The utmost limit of a person's view, where the Sky seems to touch the Earth all around, is called his Horizon; which shifts as the person changes his place.

half

half of the Heavens is ſeen; for thoſe parts which are once viſible never ſet, and thoſe which are once inviſible never riſe. But the Ecliptic *♈CX*, or Orbit which the Sun appears to deſcribe once a year by the Earth's annual motion, has the half *♈C* conſtantly above the Horizon *ECQ* of the North Pole *n*; and the other half *CX* always below it. Therefore whilſt the Sun deſcribes the northern half *♈C* of the Ecliptic, he neither ſets to the North Pole nor riſes to the South; and whilſt he deſcribes the ſouthern half *CX*, he neither ſets to the South Pole nor riſes to the North. The ſame things are true with reſpect to the Moon; only with this difference, that as the Sun deſcribes the Ecliptic but once a year, he is for half that time viſible to each Pole in it's turn, and as long inviſible; but as the Moon goes round the Ecliptic in 27 days 8 hours, ſhe is only viſible for 13 days 16 hours, and as long inviſible to each Pole by turns. All the Planets likewiſe riſe and ſet to the Poles, becauſe their Orbits are cut obliquely in halves by the Horizon of the Poles. When the Sun (in his apparent way from *X*) arrives at *C*, which is on the 20th of *March*, he is juſt riſing to an obſerver at *n* on the North Pole, and ſetting to another at *s* on the South Pole. From *C* he riſes higher and higher in every apparent Diurnal revolution, 'till he comes to the higheſt point of the Ecliptic *y*, on the 21ſt of *June*, and then he is at his greateſt Altitude, which is $23\frac{1}{2}$ degrees, or the Arc *Ey*, equal to his greateſt North declination; and from thence he ſeems to deſcend gradually in every apparent Circumvolution, 'till he ſets at *C* on the 23d of *September*; and then he goes to exhibit the like Appearances at the South Pole for the other half of the year. Hence the Sun's apparent motion round the Earth is not in parallel Circles, but in Spirals; ſuch as might be repreſented by a thread wound round a Globe from Tropic to Tropic; the Spirals being at ſome diſtance from one another about the Equator, and gradually

Phenomena at the Poles.

PLATE II. gradually nearer to each other as they approach toward the Tropics.

Phenomena at the Equator. 126. If the obſerver be any where on the Terreſtrial Equator *eCq*, as ſuppoſe at *e*, he is in the plane of the Celeſtial Equator; or under the Equinoctial *ECQ*; and the Axis of the earth *nCs* is coincident with the Plane of his Horizon, extended out to *N* and *S*, the North and South Poles of the Heavens. As the Earth turns round the line *NCS*, the whole Heavens *MOLl* ſeem to turn round the ſame line, but the contrary way. It is plain that this obſerver has the celeſtial Poles conſtantly in his Horizon, and that his Horizon cuts the Diurnal paths of all the Celeſtial bodies perpendicularly and in halves. Therefore the Sun, Planets and Stars, riſe every day, and aſcend perpendicularly above the Horizon for ſix hours, and paſſing over the Meridian, deſcend in the ſame manner for the ſix following hours; then ſet in the Horizon, and continue twelve hours below it. Conſequently at the Equator the days and nights are equally long throughout the year. When the obſerver is in the ſituation *e*, he ſees the Hemiſphere *SEN*; but in twelve hours after, he is carried half round the Earth's Axis to *q*, and then the Hemiſphere *SQN* becomes viſible to him; and *SEN* diſappears. Thus we find, that to an obſerver at either of the Poles one half of the Sky is always viſible, and the other half never ſeen; but to an obſerver on the Equator the whole Sky is ſeen every 24 hours.

Fig. I.

The Figure here referred to, repreſents a Celeſtial globe of glaſs, having a Terreſtrial globe within it; after the manner of the Glaſs Sphere invented by my generous friend Dr. Long, *Lowndes*'s Profeſſor of Aſtronomy in *Cambridge*.

Remark. 127. If a Globe be held ſidewiſe to the eye, at ſome diſtance, and ſo that neither of it's Poles can be ſeen, the Equator *ECQ*, and all Circles parallel to it, as *DL*, *yzx*, *abX*, *MO*, &c. will appear to be

ſtraight

ſtraight lines, as projected in this Figure; which is requiſite to be mentioned here, becauſe we ſhall have occaſion to call them Circles in the following Articles of this Chapter *.

Phenomena between the Equator and Poles.

128. Let us now ſuppoſe that the obſerver has gone from the Equator *e* towards the North Pole *n*, and that he ſtops at *i*, from which place he then ſees the Hemiſphere *MElNL*; his Horizon *MCL* having ſhifted as many † Degrees from the Celeſtial Poles *N* and *S*, as he has travelled from under the Equinoctial *E*. And as the Heavens ſeem conſtantly to turn round the line *NCS* as an Axis, all thoſe Stars which are not ſo many degrees from the North Pole *N* as the obſerver is from the Equinoctial, namely, the Stars north of the dotted parallel *DL*, never ſet below the Horizon; and thoſe which are ſouth of the dotted parallel *MO*, never riſe above it. Hence, the former of theſe two parallel Circles is called *the Circle of perpetual Apparition*, and the latter *the Circle of perpetual Occultation*: but all the Stars between theſe two Circles riſe and ſet every day. Let us imagine many Circles to be drawn between theſe two, and parallel to them; thoſe which are on the north ſide of the Equinoctial will be unequally cut by the Horizon *MCL*, having larger portions above the Horizon than below it; and the more ſo, as they are nearer to the Circle of perpetual Apparition; but the reverſe happens to thoſe on the ſouth ſide of the Equinoctial, whilſt the Equinoctial is divided in two equal parts by the Horizon. Hence, by the apparent turning of the Heavens, the northern Stars deſcribe greater Arcs or Portions of Circles above the Horizon than below it; and the greater, as they are farther from the Equinoctial towards the Circle of perpetual Apparition; whilſt the con-

The Circles of perpetual Apparition and Occultation.

* The Plane of a Circle, or a thin circular Plate, being turned edgewiſe to the eye, appears to be a ſtraight line.

† A Degree is the 360th part of a Circle.

trary

PLATE II. trary happens to all Stars ſouth of the Equinoctial: but thoſe upon it deſcribe equal Arcs both above and below the Horizon, and therefore they are juſt as long above as below it.

129. An obſerver on the Equator has no Circle of perpetual Apparition or Occultation, becauſe all the Stars, together with the Sun and Moon, riſe and ſet to him every day. But, as a bare view of the Figure is ſufficient to ſhew that theſe two Circles *DL* and *MO* are juſt as far from the Poles *N* and *S* as the obſerver at *i* (or one oppoſite to him at *o*) is from the Equator *ECQ*; it is plain, that if an obſerver begins to travel from the Equator towards either Pole, his Circle of perpetual Apparition riſes from that Pole as from a Point, and his Circle of perpetual Occultation from the other. As the obſerver advances toward the nearer Pole, theſe two Circles enlarge their diameters, and come nearer one another, until he comes to the Pole; and then they meet and coincide in the Equinoctial. On different ſides of the Equator, to obſervers at equal diſtances from it, the Circle of perpetual Apparition to one is the Circle of perpetual Occultation to the other.

Why the Stars always deſcribe the ſame parallel of motion, and the Sun a different.

130. Becauſe the Stars never vary their diſtances from the Equinoctial, ſo as to be ſenſible in an age, the lengths of their diurnal and nocturnal Arcs are always the ſame to the ſame places on the Earth. But as the Earth goes round the Sun every year in the Ecliptic, one half of which is on the north ſide of the Equinoctial and the other half on it's ſouth ſide, the Sun appears to change his place every day, ſo as to go once round the Circle *YCX* every year, § 114. Therefore whilſt the Sun appears to advance northward, from having deſcribed the Parallel *abX* touching the Ecliptic in *X*, the days continually lengthen and the nights ſhorten, until he comes to *y* and deſcribes the Parallel *yzx*, when the days are at the longeſt and the nights at the

the ſhorteſt: for then, as the Sun goes no farther northward, the greateſt portion that is poſſible of the diurnal Arc *yz* is above the Horizon of the inhabitant *i*; and the ſmalleſt portion *zx* below it. As the Sun declines ſouthward from *y*, he deſcribes ſmaller diurnal and greater nocturnal Arcs, or Portions of Circles, every day; which cauſeth the days to ſhorten and nights to lengthen, until he arrives again at the Parallel *abX*; which having only the ſmall part *ab* above the Horizon *MCL*, and the great part *bX* below it, the days are at the ſhorteſt and the nights at the longeſt; becauſe the Sun recedes no farther ſouth, but returns northward as before. It is eaſy to ſee that the Sun muſt be in the Equinoctial *ECQ* twice every year, and then the days and nights are equally long; that is, 12 hours each. Theſe hints ſerve at preſent to give an idea of ſome of the Appearances reſulting from the motions of the Earth; which will be more particularly deſcribed in the tenth Chapter. PLATE II.

131. To an obſerver at either Pole, the Horizon and Equinoctial are coincident; and the Sun and Stars ſeem to move parallel to the Horizon: therefore, ſuch an obſerver is ſaid to have a parallel poſition of the Sphere. To an obſerver any where between either Pole and Equator, the Parallels deſcribed by the Sun and Stars are cut obliquely by the Horizon, and therefore he is ſaid to have an Oblique poſition of the Sphere. To an obſerver any where on the Equator, the Parallels of Motion, deſcribed by the Sun and Stars, are cut perpendicularly, or at Right angles, by the Horizon; and therefore he is ſaid to have a right poſition of the Sphere. And theſe three are all the different ways that the Sphere can be poſited to all people on the Earth. Fig. I. Parallel, Oblique, and Right ſphere, what.

CHAP.

CHAP. V.

The Phenomena of the Heavens as ſeen from different Parts of the Solar Syſtem.

132. SO vaſtly great is the diſtance of the ſtarry Heavens, that if viewed from any part of the Solar Syſtem, or even many millions of miles beyond it, it's appearance would be the very ſame to us. The Sun and Stars would all ſeem to be fixed on one concave ſurface, of which the Spectator's eye would be the center. But the Planets, being much nearer than the Stars, their appearances will vary conſiderably with the place from which they are viewed.

133. If the Spectator is at reſt without their Orbits, the Planets will ſeem to be at the ſame diſtance as the Stars; but continually changing their places with reſpect to the Stars, and to one another: aſſuming various phaſes of increaſe and decreaſe like the Moon. And notwithſtanding their regular motions about the Sun, will ſometimes appear to move quicker, ſometimes ſlower, be as often to the weſt as to the eaſt of the Sun; and at their greateſt diſtances ſeem quite ſtationary. The duration, extent, and diſtance of thoſe points in the Heavens where theſe digreſſions begin and end, would be more or leſs, according to the reſpective diſtances of the ſeveral Planets from the Sun: but in the ſame Planet they would continue invariably the ſame at all times; like pendulums of unequal lengths oſcillating together, the ſhorter move quick and go over a ſmall ſpace, the longer move ſlow and go over a large ſpace. If the obſerver is at reſt within the Orbits of the Planets, but not near the common center, their apparent motions will be irregular, but leſs ſo than in the former caſe. Each of the ſeveral Planets will appear bigger and leſs by turns, as they approach nearer

nearer or recede farther from the obſerver; the neareſt varying moſt in their ſize. They will alſo move quicker or ſlower with regard to their fixed Stars, but will never be retrograde or ſtationary.

134. If an obſerver in motion views the Heavens, the ſame apparent irregularities will be obſerved, but with ſome variation reſulting from it's own motion. If he is on a Planet which has a rotation on it's Axis, not being ſenſible of his own motion, he will imagine the whole Heavens, Sun, Planets, and Stars, to revolve about him in the ſame time that his Planet turns round, but the contrary way; and will not be eaſily convinced of the deception. If his Planet moves round the Sun, the ſame irregularities and aſpects as above-mentioned will appear in the motions of the other Planets; and the Sun will ſeem to move among the fixed Stars or Signs, directly oppoſite to thoſe in which his Planet moves, changing it's place every day as he does. In a word, whether our obſerver be in motion or at reſt, whether within or without the Orbits of the Planets, their motions will ſeem irregular, intricate and perplexed, unleſs he is in the center of the Syſtem; and from thence, the moſt beautiful order and harmony will be ſeen by him.

The Sun's center the only point from which the true motions and places of the Planets could be ſeen.

135. The Sun being the center of all the Planets motions, the only place from which their motions could be truly ſeen, is the Sun's center; where the obſerver being ſuppoſed not to turn round with the Sun (which, in this caſe, we muſt imagine to be a tranſparent body) would ſee all the Stars at reſt, and ſeemingly equidiſtant from him. To ſuch an obſerver, the Planets would appear to move among the fixed Stars, in a ſimple, regular, and uniform manner; only, that as in equal times they deſcribe equal Areas, they would deſcribe ſpaces ſomewhat unequal, becauſe they move in elliptic Orbits, § 155. Their motions would alſo appear to be what they are in fact, the ſame way round the Heavens; in

would conclude thoſe Planets, whoſe periods are quickeſt, to move in Orbits proportionably leſs than thoſe do which make ſlower circuits. But being deſtitute of a method for finding their Parallaxes, or, more properly ſpeaking, as they could have no Parallax to him, he could never know any thing of their real diſtances or magnitudes. Their relative diſtances he might perhaps gueſs at by their periods, and from thence infer ſomething of truth concerning their relative bulks, by comparing their apparent bulks with one another. For example, Jupiter appearing bigger to him than Mars, he would conclude it to be much bigger in fact; becauſe it appears ſo, and muſt be farther from him, on account of it's longer period. Mercury and the Earth would ſeem much of the ſame bulk; but by comparing it's period with the Earth's, he would conclude that the Earth is much farther from him than Mercury, and conſequently that it muſt be really bigger, though apparently of the ſame bulk; and ſo of the reſt. And as each Planet would appear ſomewhat bigger in one part of it's Orbit than in the oppoſite, and to move quickeſt when it ſeems biggeſt, the obſerver would be at no loſs to determine that all the Planets move in Orbits, of which the Sun is not preciſely in the center.

137. The apparent magnitudes of the Planets continually change as ſeen from the Earth, which demonſtrates that they approach nearer to it, and recede farther from it by turns. From theſe Phenomena, and their apparent motions among the Stars, they ſeem to deſcribe looped curves which never return into themſelves, Venus's path excepted. And if we were to trace out all their apparent paths, and put the figures of them together in one diagram, they would appear ſo anomalous and confuſed, that no man in his ſenſes could believe them to be repreſentations of their real paths; but would immediately conclude, that ſuch appa-

The Planetary motions very irregular as ſeen from the Earth.

 rent

PLATE III. rent irregularities muſt be owing to ſome Optic illuſions. And after a good deal of enquiry, he might perhaps be at a loſs to find out the true cauſe of theſe inequalities; eſpecially if he were one of thoſe who would rather, with the greateſt juſtice, charge frail man with ignorance, than the Almighty with being the author of ſuch confuſion.

Thoſe of Mercury and Venus repreſented.

138. Dr. LONG, in his firſt volume of *Aſtronomy*, has given us figures of the apparent paths of all the Planets, ſeparately, from CASSINI; and on ſeeing them I firſt thought of attempting to trace ſome of them by a machine * that ſhews the motions of the Sun, Mercury, Venus, the Earth and Moon, according to the *Copernican Syſtem*. Having taken off the Sun, Mercury, and Venus, I put black-lead pencils in their places, with the points turned upward; and fixed a circular ſheet of paſte-board ſo, that the Earth kept conſtantly under it's center in going round the Sun; and the paſte-board kept it's paralleliſm. Then, preſſing gently with one hand upon the paſte-board to make it touch the three pencils, with the other hand I turned the winch that moves the whole machinery: and as the Earth, together with the pencils in the places of Mercury and Venus, had their proper motions round the Sun's pencil, which kept at reſt in the center of the machine, all the three pencils deſcribed a diagram from which the firſt Figure of the third Plate is truly copied in a ſmaller ſize. As the Earth moved round the Sun, the Sun's pencil deſcribed the dotted Circle of Months, whilſt Mercury's pencil drew the curve with the greateſt number of loops, and Venus's that with the feweſt. In their inferior conjunctions they come as much nearer the Earth, or within the Circle of the Sun's apparent motion round the Heavens, as they go beyond it in their ſuperior conjunctions. On each ſide of the loops they appear ſtationary; in that part of

Fig. I.

* The ORRERY fronting the Title-page.

each

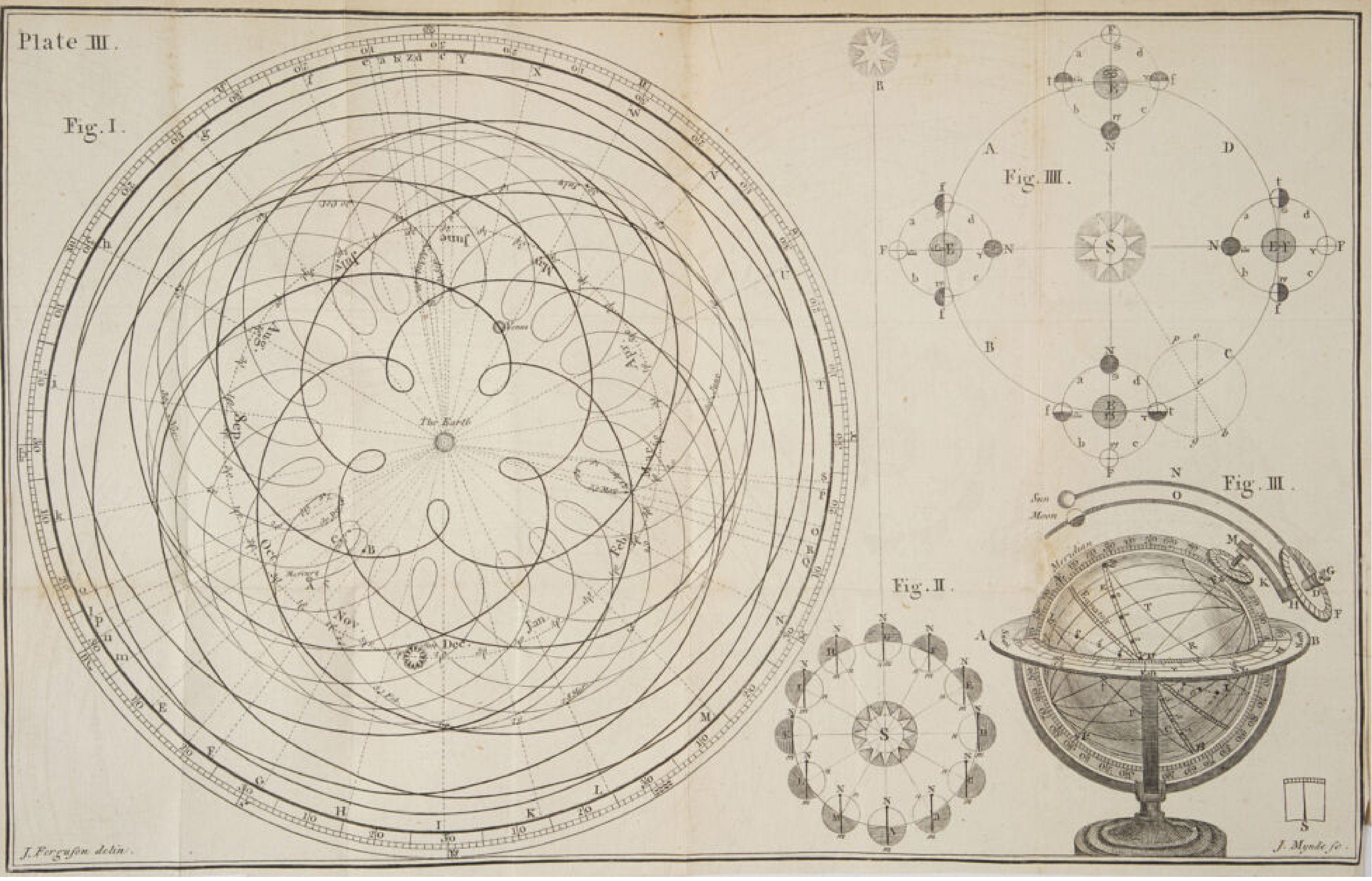


Plate III.
Fig. I.
The Earth
Fig. IIII.
Fig. III.
Fig. II.
Sun
Moon
Meridian
J. Ferguson delin.
J. Mynde sc.

each loop next the Earth retrograde; and in all the reſt of their paths direct. PLATE III.

If *Caſſini*'s Figures of the paths of the Sun, Mercury and Venus, were put together, the Figure as above traced out, would be exactly like them. It repreſents the Sun's apparent motion round the Ecliptic, which is the ſame every year; Mercury's motion for ſeven years; and Venus's for eight; in which time Mercury's path makes 23 loops, croſſing itſelf ſo many times, and Venus's only five. In eight years Venus falls ſo nearly into the ſame apparent path again, as to deviate very little from it in ſome ages; but in what number of years Mercury and the reſt of the Planets would deſcribe the ſame viſible paths over again, I cannot at preſent determine. Having finiſhed the above Figure of the paths of Mercury and Venus, I put the Ecliptic round them as in the Doctor's Book; and added the dotted lines from the Earth to the Ecliptic for ſhewing Mercury's apparent or geocentric motion therein for one year; in which time his path makes three loops, and goes on a little farther; which ſhews that he has three inferior, and as many ſuperior conjunctions with the Sun in that time; and alſo that he is ſix times ſtationary, and thrice retrograde. Let us now trace his motion for one year in the Figure.

Suppoſe Mercury to be ſetting out from *A* towards *B* (between the Earth and left-hand corner of the Plate) and as ſeen from the Earth his motion Fig. I. will then be direct, or according to the order of the Signs. But when he comes to *B*, he appears to ſtand ſtill in the 23d degree of ♏ at *F*, as ſhewn by the line *BF*. Whilſt he goes from *B* to *C*, the line *BF*, ſuppoſed to move with him, goes backward from *F* to *E*, or contrary to the order of Signs; and when he is at *C*, he appears ſtationary at *E*; having gone back 11½ degrees. Now, ſuppoſe him ſtationary on the firſt of *January* at *C*, on the 10th thereof he will appear in the Heavens as at 20, near *F*; on the 20th he will be ſeen as

at

at *G*; on the 31ſt at *H*; on the 10th of *February* at *I*; on the 20th at *K*; and on the 28th at *L*; as the dotted lines ſhew, which are drawn through every tenth day's motion in his looped path, and continued to the Ecliptic. On the 10th of *March* he appears at *M*; on the 20th at *N*; and on the 31ſt at *O*. On the 10th of *April* he appears ſtationary at *P*; on the 20th he ſeems to have gone back again to *O*; and on the 30th he appears ſtationary at *Q*, having gone back 11½ degrees. Thus Mercury ſeems to go forward 4 Signs 11 Degrees, or 131 Degrees; and to go back only 11 or 12 Degrees, at a mean rate. From the 30th of *April* to the 10th of *May*, he ſeems to move from *Q* to *R*; and on the 20th he is ſeen at *S*, going forward in the ſame manner again, according to the order of letters; and backward when they go back; which it is needleſs to explain any farther, as the reader can trace him out ſo eaſily, through the reſt of the year. The ſame appearances happen in Venus's motion; but as ſhe moves ſlower than Mercury, there are longer intervals of time between them.

Having already, § 120, given ſome account of the apparent diurnal motions of the Heavens as ſeen from the different Planets, we ſhall not trouble the reader any more with that ſubject.

CHAP. VI.

The Ptolemean *Syſtem refuted. The Motions and Phaſes of Mercury and Venus explained.*

139. THE *Tychonic Syſtem*, § 97, being ſufficiently refuted by the 109th Article, we ſhall ſay nothing more about it.

140. The *Ptolemean Syſtem*, § 96, which aſſerts the Earth to be at reſt in the Center of the Univerſe, and all the Planets with the Sun and Stars to move round it, is evidently falſe and abſurd. For

For if this hypothefis were true, Mercury and Venus could never be hid behind the Sun, as their Orbits are included within the Sun's: and again, thefe two Planets would always move direct, and be as often in Oppofition to the Sun as in Conjunction with him. But the contrary of all this is true: for they are juft as often behind the Sun as before him, appear as often to move backwards as forwards, and are fo far from being feen at any time in the fide of the Heavens oppofite to the Sun, that they were never feen a quarter of a circle in the Heavens diftant from him.

141. Thefe two Planets, when viewed at different times with a good telefcope, appear in all the various fhapes of the Moon; which is a plain proof that they are enlightened by the Sun, and fhine not by any light of their own: for if they did, they would conftantly appear round as the Sun does; and could never be feen like dark fpots upon the Sun when they pafs directly between him and us. Their regular Phafes demonftrate them to be fpherical bodies; as may be fhewn by the following experiment. Appearances of Mercury and Venus.

Hang an ivory ball by a thread, and let any Perfon move it round the flame of a candle, at two or three yards diftance from your Eye: when the ball is beyond the candle, fo as to be almoft hid by the flame, it's enlightened fide will be towards you, and appear round like the Full Moon: When the ball is between you and the candle, it's enlightened fide will difappear, as the Moon does at the Change: When it is half way between thefe two pofitions, it will appear half illuminated, like the Moon in her Quarters: But in every other place between thefe pofitions, it will appear more or lefs horned or gibbous. If this experiment be made with a flat circular plate, you may make it appear fully enlightened, or not enlightened at all; but can never make it feem either horned or gibbous. Experiment to prove they are round.

F 3 142. If

PLATE II.

Experiment to reprefent the motions of Mercury and Venus.

142. If you remove about fix or feven yards from the candle, and place yourfelf fo that it's flame may be juft about the height of your eye, and then defire the other perfon to move the ball flowly round the candle as before, keeping it as near of an equal height with the flame as he poffibly can, the ball will appear to you not to move in a circle, but to vibrate backward and forward like a pendulum, moving quickeft when it is directly between you and the candle, and when directly beyond it; and gradually flower as it goes farther to the right or left fide of the flame, until it appears at the greateft diftance from the flame; and then, though it continues to move with the fame velocity, it will feem to ftand ftill for a moment. In every Revolution it will fhew all the above Phafes, § 141; and if two balls, a fmaller and a greater, be moved in this manner round the candle, the fmaller ball being kept neareft the flame, and carried round almoft three times as often as the greater, you will have a tolerable good reprefentation of the apparent Motions of Mercury and Venus; efpecially, if the bigger ball defcribes a circle almoft twice as large in diameter as the circle defcribed by the leffer.

Fig. III.

143. Let *ABCDE* be a part or fegment of the vifible Heavens, in which the Sun, Moon, Planets and Stars, appear to move at the fame diftance from the Earth *E*. For there are certain limits, beyond which the eye cannot judge of different diftances; as is plain from the Moon's appearing to be no nearer to us than the Sun and Stars are. Let the circle *fghiklmno* be the Orbit in which Mercury *m* moves round the Sun *S*, according to the order of of the letters. When Mercury is at *f*, he difappears to the Earth at *E*, becaufe his enlightened fide is turned from it; unlefs he be then in one of his Nodes, § 20, 25; in which cafe, he will appear like a dark fpot upon the Sun. When he is at *g* in his Orbit, he appears at *B* in the Heavens, weft-ward

The Elongations or Digreffions of Mercury from the Sun.

ward of the Sun *S*, which is ſeen at *C*: when at *h*, he appears at *A*, at his greateſt weſtern elongation or diſtance from the Sun; and then ſeems to ſtand ſtill. But, as he moves from *h* to *i*, he appears to go from *A* to *B*; and ſeems to be in the ſame place when at *i* as when he was at *g*, only not near ſo big: at *k* he is hid from the Earth *E* by the Sun *S*; being then in his ſuperior Conjunction. In going from *k* to *l*, he appears to move from *C* to *D*; and when he is at *n*, he appears ſtationary at *E*; being ſeen as far eaſt from the Sun then, as he was weſt from him at *A*. In going from *n* to *o* in his Orbit, he ſeems to go back again in the Heavens, from *E* to *D*; and is ſeen in the ſame place (with reſpect to the Sun) at *o*, as when he was at *l*; but of a larger diameter at *o*, becauſe he is then nearer the Earth *E*: and when he comes to *f*, he again paſſes by the Sun, and diſappears as before. In going from *n* to *h* in his Orbit, he ſeems to go backward in the Heavens from *E* to *A*; and in going from *h* to *n*, he ſeems to go forward from *A* to *E*. As he goes on from *f*, a little of his enlightened ſide at *g* is ſeen from *E*; at *h* he appears half full, becauſe half of his enlightened ſide is ſeen; at *i*, gibbous, or more than half full; and at *k* he would appear quite full, were he not hid from the Earth *E* by the Sun *S*. At *l* he appears gibbous again; at *n* half decreaſed, at *o* horned, and at *f* new like the Moon at her Change. He goes ſooner from his eaſtern ſtation at *n* to his weſtern ſtation at *h*, than from *h* to *n* again; becauſe he goes through leſs than half his Orbit in the former caſe, and more in the latter. PLATE II.

144. In the ſame Figure, let *FGHIKLMN* be the Orbit in which Venus *v* moves round the Sun *S*, according to the order of the letters: and let *E* be the Earth as before. When Venus is at *F*, ſhe is in her inferior Conjunction; and diſappears like the New Moon, becauſe her dark ſide is toward the Earth. At *G*, ſhe appears half enlightened Fig. III.

The Elongations and Phaſes of Venus.

 to

to the Earth, like the Moon in her firſt quarter: at *H*, ſhe appears gibbous; at *I*, almoſt full; her enlightened ſide being then nearly towards the Earth: at *K*, ſhe would appear quite full to the Earth *E*; but is hid from it by the Sun *S*: at *L*, ſhe appears upon the decreaſe, or gibbous; at *M*, more ſo; at *N*, only half enlightened; and at *F*, ſhe diſappears again. In moving from *N* to *G*, ſhe ſeems to go backward in the Heavens; and from *G* to *N*, forward: but, as ſhe deſcribes a much greater portion of her Orbit in going from *G* to *N*, than from *N* to *G*, ſhe appears much longer direct than retrograde in her motion. At *N* and *G* ſhe appears ſtationary; as Mercury does at *n* and *h*. Mercury, when ſtationary, ſeems to be only 28 degrees from the Sun; and Venus, when ſo, 47; which is a demonſtration that Mercury's Orbit is included within Venus's, and Venus's within the Earth's.

The greateſt Elongations of Mercury and Venus.

Morning and Evening Star, what.

145. Venus, from her ſuperior Conjunction at *K* to her inferior Conjunction at *F*, is ſeen on the eaſt ſide of the Sun *S* from the Earth *E*; and therefore ſhe ſhines in the Evening after the Sun ſets, and is called *the Evening Star*: for, the Sun being then to the weſtward of Venus, he muſt ſet firſt. From her inferior Conjunction to her ſuperior, ſhe appears on the weſt ſide of the Sun; and therefore riſes before him, for which reaſon ſhe is called *the Morning Star*. When ſhe is about *N* or *G*, ſhe ſhines ſo bright, that bodies caſt ſhadows in the night-time.

146. If the Earth kept always at *E*, it is evident that the ſtationary places of Mercury and Venus would always be in the ſame points of the Heavens where they were before. For example; whilſt Mercury *m* goes from *h* to *n*, according to the order of the letters, he appears to deſcribe the arc *ABCDE* in the Heavens, direct: and whilſt he goes from *n* to *h*, he ſeems to deſcribe the ſame arc back again, from *E* to *A*, retrograde: always at

The ſtationary places of the Planets variable.

at *n* and *b* he appears ſtationary at the ſame points *E* and *A* as before. But Mercury goes round his Orbit, from *f* to *f* again, in 88 days; and yet there are 116 days from any one of his Conjunctions, or apparent Stations, to the ſame again: and the places of theſe Conjunctions and Stations are found to be about 114 degrees eaſtward from the points of the Heavens where they were laſt before; which proves that the Earth has not kept all that time at *E*, but has had a progreſſive motion in it's Orbit from *E* to *t*. Venus alſo differs every time in the places of her Conjunctions and Stations; but much more than Mercury; becauſe, as Venus deſcribes a much larger Orbit than Mercury does, the Earth advances ſo much the farther in it's annual path before Venus comes round again.

147. As Mercury and Venus, ſeen from the Earth, have their reſpective Elongations from the Sun, and ſtationary places; ſo has the Earth, ſeen from Mars; and Mars, ſeen from Jupiter; and Jupiter, ſeen from Saturn. That is, to every ſuperior Planet, all the inferior ones have their Stations and Elongations; as Venus and Mercury have to the Earth. As ſeen from Saturn, Mercury never goes more than $2\frac{1}{2}$ degrees from the Sun; Venus $4\frac{1}{3}$; the Earth 6; Mars $9\frac{1}{2}$; and Jupiter $33\frac{1}{4}$: ſo that Mercury, as ſeen from the Earth, has almoſt as great a Digreſſion or Elongation from the Sun, as Jupiter ſeen from Saturn. The Elongations of all Saturn's inferior Planets as ſeen from him.

148. Becauſe the Earth's Orbit is included within the Orbits of Mars, Jupiter, and Saturn, they are ſeen on all ſides of the Heavens; and are as often in Oppoſition to the Sun as in Conjunction with him. If the Earth ſtood ſtill, they would always appear direct in their motions; never retrograde nor ſtationary. But they ſeem to go juſt as often backward as forward; which, if gravity be allowed to exiſt, affords a ſufficient proof of the Earth's annual motion: and without it's exiſtence, the Planets could never fall from the tangents of A proof of the Earth's annual motion.

their

PLATE II. their Orbits towards the Sun, nor could a ſtone which is once thrown up from the Earth ever fall to the Earth again.

149. As Venus and the Earth are ſuperior Planets to Mercury, they ſhew much the ſame Appearances to him that Mars and Jupiter do to us. Let Mercury *m* be at *f*, Venus *v* at *F*, and the Earth at *E*; in which ſituation Venus hides the Earth from Mercury; but, being in oppoſition to the Sun, ſhe ſhines on Mercury with a full illumined Orb; though, with reſpect to the Earth, ſhe is in conjunction with the Sun, and inviſible. When Mercury is at *f*, and Venus at *G*, her enlightened ſide not being directly towards him, ſhe appears a little gibbous; as Mars does in a like ſituation to us: but, when Venus is at *I*, her enlightened ſide is ſo much towards Mercury at *f*, that ſhe appears to him almoſt of a round figure. At *K*, Venus diſappears to Mercury at *f*, being then hid by the Sun; as well as all our ſuperior Planets are to us, when in conjunction with the Sun. When Venus has, as it were, emerged out of the Sun beams, as at *L*, ſhe appears almoſt full to Mercury at *f*; at *M* and *N*, a little gibbous; quite full at *F*, and largeſt of all; being then in oppoſition to the Sun, and conſequently neareſt to Mercury at *f*; ſhining ſtrongly on him in the night, becauſe her diſtance from him then is ſomewhat leſs than a fifth part of her diſtance from the Earth, when ſhe appears roundeſt to it between *I* and *K*, or between *K* and *L*, as ſeen from the Earth *E*. Conſequently, when Venus is oppoſite to the Sun as ſeen from Mercury, ſhe appears more than 25 times as large to him as ſhe does to us when at the fulleſt. Our caſe is almoſt ſimilar with reſpect to Mars, when he is oppoſite to the Sun; becauſe he is then ſo near the Earth, and has his whole enlightened ſide towards it. But, becauſe the Orbits of Jupiter and Saturn are very large in proportion to the Earth's Orbit, theſe two Planets appear much leſs magnified

Fig. III. General Phenomena of a ſuperior Planet to an inferior.

fied at their Oppositions, or diminished at their Conjunctions, than Mars does, in proportion to their mean apparent Diameters. PLATE II.

CHAP. VII.

The physical Causes of the Motions of the Planets. The Excentricities of their Orbits. The Times in which the Action of Gravity would bring them to the Sun. ARCHIMEDES's *ideal Problem for moving the Earth. The World not eternal.*

150. FROM the uniform projectile motion of bodies in straight lines, and the universal power of attraction which draws them off from these lines, the curvilineal motions of all the Planets arise. If the body *A* be projected along the right line *ABX*, in open Space, where it meets with no resistance, and is not drawn aside by any other power, it will for ever go on with the same velocity, and in the same direction. For, the force which moves it from *A* to *B* in any given time, will carry it from *B* to *X* in as much more time, and so on, there being nothing to obstruct or alter it's motion. But if, when this projectile force has carried it, suppose to *B*, the body *S* begins to attract it, with a power duly adjusted, and perpendicular to it's motion at *B*, it will then be drawn from the straight line *ABX*, and forced to revolve about *S* in the Circle *BYTU*. When the body *A* comes to *U*, or any other part of it's Orbit, if the small body *u*, within the sphere of *U*'s attraction, be projected as in the right line *Z*, with a force perpendicular to the attraction of *U*, then *u* will go round *U* in the Orbit *W*, and accompany it in it's whole course round the body *S*. Here, *S* may represent the Sun, *U* the Earth, and *u* the Moon.

Gravitation and Projection. Fig. IV.

Circular Orbits.

Fig. IV.

151. If a Planet at *B* gravitates, or is attracted, toward the Sun, so as to fall from *B* to *y* in the

time that the projectile force would have carried it from B to X, it will describe the curve BY by the combined action of these two forces, in the same time that the projectile force singly would have carried it from B to X, or the gravitating power singly have caused it to descend from B to y; and these two forces being duly proportioned, and perpendicular to one another, the Planet obeying them both, will move in the circle $BYTU$*.

152. But if, whilst the projectile force carries the Planet from B to b, the Sun's attraction (which constitutes the Planet's gravitation) should bring it down from B to 1, the gravitating power would then be too strong for the projectile force; and would cause the Planet to describe the curve BC. When the Planet comes to C, the gravitating power (which always increases as the square of the distance from the Sun S diminishes) will be yet stronger for the projectile force; and by conspiring in some degree therewith, will accelerate the Planet's motion all the way from C to K; causing it to to describe the arcs BC, CD, DE, EF, &c. all in equal times. Having it's motion thus accelerated, it thereby gains so much centrifugal force, or tendency to fly off at K in the line Kk, as overcomes the Sun's attraction: and the centrifugal force being too great to allow the Planet to be brought nearer the Sun, or even to move round him in the Circle $Klmn$, &c. it goes off, and ascends in the curve $KLMN$, &c. it's motion decreasing as gradually from K to B, as it increased from B to K, because the Sun's attraction now acts against the Planet's projectile motion just as much as it acted with it before. When the Planet has got round to B, it's projectile force is as much diminished from it's mean state about

Elliptical Orbits.

* To make the projectile force balance the gravitating power so exactly, as that the body may move in a Circle, the projectile velocity of the body must be such as it would have acquired by gravity alone in falling through half the radius of the circle.

G or

G or *N*, as it was augmented at *K*; and so, the Sun's attraction being more than sufficient to keep the Planet from going off at *B*, it describes the the same Orbit over again, by virtue of the same forces or powers. PLATE II.

153. A double projectile force will always balance a quadruple power of gravity. Let the Planet at *B* have twice as great an impulse from thence towards *X*, as it had before; that is, in the same length of time that it was projected from *B* to *b*, as in the last example, let it now be projected from *B* to *c*; and it will require four times as much gravity to retain it in it's Orbit: that is, it must fall as far as from *B* to 4 in the time that the projectile force would carry it from *B* to *c*; otherwise it could not describe the curve *BD*, as is evident by the Figure. But, in as much time as the Planet moves from *B* to *C* in the higher part of it's Orbit, it moves from *I* to *K*, or from *K* to *L*, in the lower part thereof; because, from the joint action of these two forces, it must always describe equal Areas in equal times, throughout it's annual course. These Areas are represented by the triangles *BSC*, *CSD*, *DSE*, *ESF*, &c. whose contents are equal to one another, quite round the Figure.

Fig. IV.

The Planets describe equal Areas in equal times.

154. As the Planets approach nearer the Sun, and recede farther from him, in every Revolution; there may be some difficulty in conceiving the reason why the power of gravity, when it once gets the better of the projectile force, does not bring the Planets nearer and nearer the Sun in every Revolution, till they fall upon and unite with him. Or why the projectile force, when it once gets the better of gravity, does not carry the Planets farther and farther from the Sun, till it removes them quite out of the sphere of his attraction, and causes them to go in straight lines for ever afterward. But by considering the effects of these powers as described in the two last Articles, this difficulty will be removed.

A difficulty removed.

moved. Suppose a Planet at *B* to be carried by the projectile force as far as from *B* to *b*, in the time that gravity would have brought it down from *B* to 1: by these two forces it will describe the curve *BC*. When the Planet comes down to *K*, it will be but half as far from the Sun *S* as it was at *B*; and therefore, by gravitating four times as strongly towards him, it would fall from *K* to *V* in the same length of time that it would have fallen from *B* to 1 in the higher part of it's Orbit, that is, through four times as much space; but it's projectile force is then so much increased at *K*, as would carry it from *K* to *k* in the same time; being double of what it was at *B*, and is therefore too strong for the gravitating power, either to draw the Planet to the Sun, or cause it to go round him in the circle *Klmn*, &c. which would require it's falling from *K* to *w*, through a greater space than gravity can draw it, whilst the projectile force is such as would carry it from *K* to *k*: and therefore the Planet ascends in it's Orbit *KLMN*, decreasing in it's velocity for the causes already assigned in § 152.

The Planetary Orbits elliptical.

155. The Orbits of all the Planets are Ellipses, very little different from Circles: but the Orbits of the Comets are very long Ellipses; and the lower focus of them all is in the Sun. If we suppose the mean distance (or middle between the greatest and least) of every Planet and Comet from the Sun to be divided into 1000 equal parts, the Excentricities of their Orbits, both in such parts and in *English* miles, will be as follow. Mercury's, 210 parts, or 6,720,000 miles; Venus's, 7 parts, or 413,000 miles; the Earth's, 17 parts, or 1,377.000 miles; Mars's, 93 parts, or 11,439,000 miles; Jupiter's, 48 parts, or 20,352,000 miles; Saturn's, 55 parts, or 42,735,000 miles. Of the nearest of the three forementioned Comets, 1,458,000 miles; of the middlemost, 2,025,000,000 miles; and of the outermost, 6,600,000,000.

Their Excentricities.

156. By

156. By the above-mentioned law, § 150 & *seq.* bodies will move in all kinds of Ellipses, whether long or short, if the spaces they move in be void of resistance. Only, those which move in the longer Ellipses, have so much the less projectile force impressed upon them in the higher parts of their Orbits; and their velocities, in coming down towards the Sun, are so prodigiously increased by his attraction, that their centrifugal forces in the lower parts of their Orbits are so great, as to overcome the Sun's attraction there, and cause them to ascend again towards the higher parts of their Orbits; during which time, the Sun's attraction acting so contrary to the motions of those bodies, causes them to move slower and slower, until their projectile forces are diminished almost to nothing; and then they are brought back again by the Sun's attraction, as before.

The above laws sufficient for motions both in circular and elliptic Orbits.

157. If the projectile forces of all the Planets and comets were destroyed at their mean distances from the Sun, their gravities would bring them down so, as that Mercury would fall to the Sun in 15 days 13 hours; Venus in 39 days 17 hours; the Earth or Moon in 64 days 10 hours; Mars in 121 days; Jupiter in 290; and Saturn in 767. The nearest Comet in 13 thousand days; the middlemost in 23 thousand days; and the outermost in 66 thousand days. The Moon would fall to the Earth in 4 days 20 hours; Jupiter's first Moon would fall to him in 7 hours, his second in 15, his third in 30, and his fourth in 71 hours. Saturn's first Moon would fall to him in 8 hours, his second in 12, his third in 19, his fourth in 68 hours, and his fifth in 336. A stone would fall to the Earth's center, if there were an hollow passage, in 21 minutes 9 seconds. Mr. Whiston gives the following Rule for such Computations. "* It is demonstrable, that half the Period of any Planet, when it is diminished in the sesquialteral propor-

In what times the Planets would fall to the Sun by the power of gravity.

* Astronomical Principles of Religion, p. 66.

tion

tion of the number 1 to the number 2, or nearly in the proportion of 1000 to 2828, is the time that it would fall to the center of it's Orbit." This proportion is, when a quantity or number contains another once and a half as much more.

The prodigious attraction of the Sun and Planets.

158. The quick motions of the Moons of Jupiter and Saturn round their Primaries, demonſtrate that theſe two Planets have ſtronger attractive powers than the Earth has. For, the ſtronger that one body attracts another, the greater muſt be the projectile force, and conſequently the quicker muſt be the motion of that other body to keep it from falling to it's primary or central Planet. Jupiter's ſecond Moon is 124 thouſand miles farther from Jupiter than our Moon is from us; and yet this ſecond Moon goes almoſt eight times round Jupiter whilſt our Moon goes only once round the Earth. What a prodigious attractive power muſt the Sun then have, to draw all the Planets and Satellites of the Syſtem towards him; and what an amazing power muſt it have required to put all theſe Planets and Moons into ſuch rapid Motions at firſt! Amazing indeed to us, becauſe impoſſible to be effected by the ſtrength of all the living Creatures in an unlimited number of Worlds; but no ways hard for the Almighty, whoſe Planetarium takes in the whole Univerſe!

ARCHIMEDES's Problem for raiſing the Earth.

159. The celebrated ARCHIMEDES affirmed he could move the Earth, if he had a place at a diſtance from it to ſtand upon to manage his machinery*. This aſſertion is true in Theory, but, upon examination, will be found abſolutely impoſſible in fact, even though a proper place and materials of ſufficient ſtrength could be had.

The ſimpleſt and eaſieſt method of moving a heavy body a little way is by a lever or crow, where a ſmall weight or power applied to the long arm

* Δὸς πȣ̃ ςῶ, καὶ τὸν κοσμὸν κινήσω, *i. e.* Give me a place to ſtand on, and I ſhall move the Earth.

will raiſe a great weight on the ſhort one. But then, the ſmall weight muſt move as much quicker than the great weight, as the latter is heavier than the former; and the length of the long arm of the lever to the length of the ſhort arm muſt be in the ſame proportion. Now, ſuppoſe a man pulls or preſſes the end of the long arm with the force of 200 pound weight, and that the Earth contains in round numbers, 4,000,000,000,000,000,000,000 or 4000 Trillions of cubic feet, each at a mean rate weighing 100 pound; and that the prop or center of motion of the lever is 6000 miles from the Earth's center: in this caſe, the length of the lever from the *Fulcrum* or center of motion to the moving power or weight ought to be 12,000,000,000,000,000,000,000,000 or 12 Quadrillions of miles; and ſo many miles muſt the power move, in order to raiſe the Earth but one mile: whence it is eaſy to compute, that if ARCHIMEDES, or the power applied, could move as ſwift as a cannon-bullet, it would take 27,000,000,000,000 or 27 Billions of years to raiſe the Earth one inch.

If any other machine, ſuch as a combination of wheels and ſcrews, was propoſed to move the Earth, the time it would require, and the ſpace gone through by the hand that turned the machine, would be the ſame as before. Hence we may learn, that however boundleſs our Imagination and Theory may be, the actual operations of man are confined within narrow bounds; and more ſuited to our real wants than to our deſires.

160. The Sun and Planets mutually attract each other: the power by which they do ſo we call *Gravity*. But whether this power be mechanical or no, is very much diſputed. Obſervation proves that the Planets diſturb one another's motions by it, and that it decreaſes according to the ſquares of the diſtances of the Sun and Planets; as light, which is known to be material, likewiſe does. Hard to determine what Gravity is.

G Hence

Hence Gravity should seem to arise from the agency of some subtle matter pressing towards the Sun and Planets, and acting, like all mechanical causes, by contact. But on the other hand, when we consider that the degree or force of Gravity is exactly in proportion to the quantities of matter in those bodies, without any regard to their bulks or quantities of surface, acting as freely on their internal as external parts; it seems to surpass the power of mechanism; and to be either the immediate agency of the Deity, or effected by a law originally established and imprest on all matter by him. But some affirm that matter, being altogether inert, cannot be impressed with any Law, even by almighty Power: and that the Deity, or some subordinate intelligence, must therefore be constantly impelling the Planets toward the Sun, and moving them with the same irregularities and disturbances which Gravity would cause, if it could be supposed to exist. But, if a man may venture to publish his own thoughts, it seems to me no greater absurdity, to suppose the Deity capable of infusing a Law, or what Laws he pleases, into matter, than to suppose him capable of giving it existence at first. The manner of both is equally inconceivable to us; but neither of them imply a contradiction in our ideas: and what implies no contradiction, is within the power of Omnipotence.

161. That the projectile force was at first given by the Deity is evident. For, since matter can never put itself in motion, and all bodies may be moved in any direction whatsoever; and yet the Planets, both primary and secondary, move from west to east, in planes nearly coincident; whilst the Comets move in all directions, and in planes very different from one another; these motions can be owing to no mechanical cause or necessity, but to the free will and power of an intelligent Being.

162. Whatever Gravity be, it is plain that it acts every moment of time: for should it's action cease, the projectile force would instantly carry off the Planets in straight lines from those parts of their Orbits where Gravity left them. But, the Planets being once put into motion, there is no occasion for any new projectile force, unless they meet with some resistance in their Orbits; nor for any mending hand, unless they disturb one another too much by their mutual attractions.

163. It is found that there are disturbances among the Planets in their motions, arising from their mutual attractions when they are in the same quarter of the Heavens; and the best modern observers find that our years are not always precisely of the same length*. Besides, there is reason to believe that the Moon is somewhat nearer the Earth now than she was formerly; her periodical month being shorter than it was in former ages. For, our Astronomical Tables, which in the present Age shew the times of Solar and Lunar Eclipses to great precision, do not answer so well for very ancient Eclipses. Hence it appears, that the Moon does not move in a medium void of all resistance, § 174; and therefore her projectile force being a little weakened, whilst there is nothing to diminish her gravity, she must be gradually approaching nearer the Earth, describing smaller and smaller Circles round it in every Revolution, and finishing her Period sooner, although her absolute motion

The Planets disturb one another's motions.

The consequences thereof.

* If the Planets did not act mutually upon one another, the areas described by them would be exactly proportionate to the times of description, § 153. But observations prove that these areas are not in such exact proportion, and are most varied when the greatest number of Planets are in any particular quarter of the Heavens. When any two Planets are in conjunction, their mutual attractions, which tend to bring them nearer to one another, draws the inferior one a little farther from the Sun, and the superior one a little nearer to him; by which means, the figure of their Orbits is somewhat altered; but this alteration is too small to be discovered in several ages.

with regard to ſpace be not ſo quick now as it was formerly: and, therefore, ſhe muſt come to the Earth at laſt; unleſs that Being, which gave her a ſufficient projectile force at the beginning, adds a little more to it in due time. And, as all the Planets move in ſpaces full of ether and light, which are material ſubſtances, they too muſt meet with ſome reſiſtance. And therefore, if their gravities are not diminiſhed, nor their projectile forces increaſed, they muſt neceſſarily approach nearer and nearer the Sun, and at length fall upon and unite with him.

The World not eternal. 164. Here we have a ſtrong philoſophical argument againſt the eternity of the World. For, had it exiſted from eternity, and been left by the Deity to be governed by the combined actions of the above forces or powers, generally called Laws, it had been at an end long ago. And if it be left to them, it muſt come to an end. But we may be certain that it will laſt as long as was intended by it's Author, who ought no more to be found fault with for framing ſo periſhable a work, than for making man mortal.

CHAP. VIII.

Of Light. It's proportional quantities on the different Planets. It's Refractions in Water and Air. The Atmoſphere; it's weight and properties. The Horizontal Moon.

165. LIGHT conſiſts of exceeding ſmall particles of matter iſſuing from a luminous body; as from a lighted candle ſuch particles of matter conſtantly flow in all directions. Dr. NIEWENTYT* computes, that in one ſecond of time there flows 418,660,000,000,000,000,000,000,000,000,000,000,000,000,000,000 particles of light out of a burning candle; which number contains at leaſt

* Religious Philoſopher, Vol. III. page 65.

6,337,

6,337,242,000,000 times the number of grains of ſand in the whole Earth; ſuppoſing 100 grains of ſand to be equal in length to an inch, and conſequently, every cubic inch of the Earth to contain one million of ſuch grains.

The dreadful effects that would enſue from their being larger.

166. Theſe amazingly ſmall particles, by ſtriking upon our eyes, excite in our minds the idea of light: and, if they were ſo large as the ſmalleſt particles of matter diſcernible by our beſt microſcopes, inſtead of being ſerviceable to us, they would ſoon deprive us of ſight by the force ariſing from their immenſe velocity, which is above 164 thouſand miles every ſecond *, or 1,230,000 times ſwifter than the motion of a cannon-bullet. And therefore, if the particles of light were ſo large, that a million of them were equal in bulk to an ordinary grain of ſand, we durſt no more open our eyes to the light, than ſuffer ſand to be ſhot point blank againſt them.

How objects become viſible to us.

167. When theſe ſmall particles, flowing from the Sun or from a candle, fall upon bodies, and are thereby reflected to our eyes, they excite in us the idea of that body, by forming it's picture on the retina †. And ſince bodies are viſible on all ſides, light muſt be reflected from them in all directions.

The rays of Light naturally move in ſtraight lines.

168. A ray of light is a continued ſtream of theſe particles, flowing from any viſible body in a ſtraight line. That the rays move in ſtraight, and not in crooked lines, unleſs they be refracted, is evident from bodies not being viſible if we endeavour to look at them through the bore of a bended pipe; and from their ceaſing to be ſeen by the interpoſition of other bodies, as the fixed Stars by the interpoſition of the Moon and Planets, and the Sun wholely or in part by the interpoſition of the Moon, Mercury, or Venus. And that theſe rays do not interfere, or joſtle one another out of

A proof that they hinder not one another's motions.

* This will be demonſtrated in the eleventh Chapter.

† A fine net-work membrane in the bottom of the eye.

PLATE II. their ways, in flowing from different bodies all around, is plain from the following Experiment. Make a little hole in a thin plate of metal, and ſet the plate upright on a table, facing a row of lighted candles ſtanding by one another; then place a ſheet of paper or paſteboard at a little diſtance from the other ſide of the plate, and the rays of all the candles, flowing through the hole, will form as many ſpecks of light on the paper as there are candles before the plate; each ſpeck as diſtinct and large, as if there were only one candle to caſt one ſpeck; which ſhews that the rays are no hinderance to each other in their motions, although they all croſs in the hole.

169. Light, and therefore heat ſo far as it depends on the Sun's rays (§ 85, towards the end) decreaſes in proportion to the ſquares of the diſtances of the Planets from the Sun. This is eaſily demonſtrated by a Figure which, together with it's deſcription, I have taken from Dr. SMITH's Optics *. Let the light which flows from a point *A*, and paſſes through a ſquare hole *B*, be received upon a plane *C*, parallel to the plane of the hole; or, if you pleaſe, let the figure *C* be the ſhadow of the plane *B*; and when the diſtance *C* is double of *B*, the length and breadth of the ſhadow *C* will be each double of the length and breadth of the plane *B*; and treble when *AD* is treble of *AB*; and ſo on: which may be eaſily examined by the light of a candle placed at *A*. Therefore the ſurface of the ſhadow *C*, at the diſtance *AC* double of *AB*, is diviſible into four ſquares, and at a treble diſtance, into nine ſquares, ſeverally equal to the ſquare *B*, as repreſented in the Figure. The light then which falls upon the plane *B*, being ſuffered to paſs to double that diſtance, will be uniformly ſpread over four times the ſpace, and conſequently will be four times

Fig. XI.

In what proportion light and heat decreaſe at any given diſtance from the Sun.

* Book I. Art. 57.

thinner

thinner in every part of that ſpace; and at a treble distance, it will be nine times thinner; and at a quadruple diſtance, ſixteen times thinner, than it was at firſt; and ſo on, according to the increaſe of the ſquare ſurfaces *B*, *C*, *D*, *E*, built upon the diſtances *AB*, *AC*, *AD*, *AE*. Conſequently, the quantities of this rarefied light received upon a ſurface of any given ſize and ſhape whatever, removed ſucceſſively to theſe ſeveral diſtances, will be but one quarter, one ninth, one ſixteenth of the whole quantity received by it at the firſt diſtance *AB*. Or in general words, the denſities and quantities of light, received upon any given plane, are diminiſhed in the ſame proportion, as the ſquares of the diſtances of that plane, from the luminous body, are increaſed: and on the contrary, are increaſed in the ſame proportion as theſe ſquares are diminiſhed. PLATE II.

170. The more a teleſcope magnifies the diſks of the Moon and Planets, they appear ſo much dimmer than to the bare eye; becauſe the teleſcope cannot magnify the quantity of light, as it does the ſurface; and, by ſpreading the ſame quantity of light over a ſurface ſo much larger than the naked eye beheld, juſt ſo much dimmer muſt it appear when viewed by a teleſcope than by the bare eye. Why the Planets appear dimmer when viewed thro' teleſcopes than by the bare eye.

171. When a ray of light paſſes out of one medium * into another, it is refracted, or turned out of it's firſt courſe, more or leſs, as it falls more or leſs obliquely on the refracting ſurface which divides the two mediums. This may be proved by ſeveral experiments; of which we ſhall only give three for example's ſake. 1. In a baſon *FGH* put a piece of money as *DB*, and then retire from it as to *A*, till the edge of the baſon at *E* juſt hides the money from your ſight: then, keep- Fig. VIII.

* A medium, in this ſenſe, is any tranſparent body, or that through which the rays of light can paſs; as water, glaſs, diamond, air; and even a vacuum is ſometimes called a Medium.

ing your head ſteady, let another perſon fill the baſon gently with water. As he fills it, you will ſee more and more of the piece *DB*; which will be all in view when the baſon is full, and appear as if lifted up to *C*. For, the ray *AEB*, which was ſtraight whilſt the baſon was empty, is now bent at the ſurface of the water in *E*, and turned out of it's rectilineal courſe into the direction *ED*. Or, in other words, the ray *DEK*, that proceeded in a ſtraight line from the edge *D* whilſt the baſon was empty, and went above the eye at *A*, is now bent at *E*; and inſtead of going on in the rectilineal direction *DEK*, goes in the angled direction *DEA*, and by entering the eye at *A* renders the object *DB* viſible. Or, 2dly, place the baſon where the Sun ſhines obliquely, and obſerve where the ſhadow of the rim *E* falls on the bottom, as at *B*: then fill it with water, and the ſhadow will fall at *D*; which proves, that the rays of light, falling obliquely on the ſurface of the water, are refracted, or bent downwards into it.

Refraction of the rays of light.

172. The leſs obliquely the rays of light fall upon the ſurface of any medium, the leſs they are refracted; and if they fall perpendicularly thereon, they are not refracted at all. For, in the laſt experiment, the higher the Sun riſes, the leſs will be the difference between the places where the edge of the ſhadow falls, in the empty and full baſon. And, 3dly, if a ſtick be laid over the baſon, and the Sun's rays be reflected perpendicularly into it from a looking-glaſs, the ſhadow of the ſtick will fall upon the ſame place of the bottom, whether the baſon be full or empty.

173. The denſer that any medium is, the more is light refracted in paſſing through it.

The Atmoſphere.

174. The Earth is ſurrounded by a thin fluid maſs of matter, called the *Air*, or *Atmoſphere*, which gravitates to the Earth, revolves with it in it's diurnal motion, and goes round the Sun with

it

it every year. This fluid is of an elaſtic or ſpringy nature, and it's lowermoſt parts being preſſed by the weight of all the Air above them, are ſqueezed the cloſer together; and are therefore denſeſt of all at the Earth's ſurface, and gradually rarer the higher up. "It is well known * that the Air near the ſurface of our Earth poſſeſſes a ſpace about 1200 times greater than Water of the ſame weight. And therefore, a cylindric column of Air 1200 feet high is of equal weight with a cylinder of Water of the ſame breadth, and but one foot high. But a cylinder of Air reaching to the top of the Atmoſphere is of equal weight with a cylinder of Water about 33 feet high †; and therefore if from the whole cylinder of Air, the lower part of 1200 feet high is taken away, the remaining upper part will be of equal weight with a cylinder of Water 32 feet high; wherefore, at the height of 1200 feet, or two furlongs, the weight of the incumbent Air is leſs, and conſequently the rarity of the compreſſed Air is greater than near the Earth's ſurface, in the ratio of 33 to 32. And having this ratio, we may compute the rarity of the Air at all heights whatſoever, ſuppoſing the expanſion thereof to be reciprocally proportional to it's compreſſion; and this proportion has been proved by the experiments of Dr. *Hooke* and others. The reſult of the computation I have ſet down in the annexed Table; in the firſt column of which you have the height of the Air in miles, whereof 4000 make a ſemi-diameter of the Earth; in the ſecond the compreſſion of the Air, or the incumbent weight; in the third it's rarity or expanſion, ſuppoſing gravity to decreaſe in the duplicate ratio of the diſtances from the Earth's center. And the ſmall numeral figures are here uſed to ſhew what number of cyphers muſt be joined

* NEWTON's *Syſtem of the World*, p. 120.

† This is evident from pumps, ſince none can draw water higher than 33 feet.

to

to the numbers expressed by the larger figures, as $0.^{17}1224$ for 0.000000000000000001224, and 26956^{15} for 26956000000000000000.

The Air's compression and rarity at different heights.

Air's		
Height.	Compression.	Expansion.
0	33	. . . 1
5	17.8515 . .	. . 1.8486
10	9.6717 . .	. . 3.4151
20	2.852 . . .	. . 11.571
40	0.2525 . .	. 136.83
400	$0.^{17}1224$.	26956^{15}
4000	$0.^{105}4465$	73907^{102}
40000	$0.^{192}1628$	26263^{189}
400000	$0.^{210}7895$	41798^{207}
4000000	$0.^{212}9878$	33414^{209}
Infinite	$0.^{212}9941$	54622^{209}

From the above Table it appears that the Air in proceeding upwards is rarefied in such manner, that a sphere of that Air which is nearest the Earth but of one inch diameter, if dilated to an equal rarefaction with that of the Air at the height of ten semi-diameters of the Earth, would fill up more space than is contained in the whole Heavens on this side the fixed Stars." And it likewise appears that the Moon does not move in a perfectly free and unresisting medium; although the Air, at a height equal to her distance, is at least 34000^{190} times thinner than at the Earth's surface; and therefore cannot resist her motion, so as to be sensible in many ages.

Its weight how found.

175. The weight of the Air, at the Earth's surface, is found by experiments made with the air-pump; and also by the quantity of mercury that the Atmosphere balances in the barometer; in which, at a mean state, the mercury stands $29\frac{1}{2}$ inches high. And if the tube were a square inch wide, it would at that height contain $29\frac{1}{2}$ cubic inches of mercury, which is just 15 pound weight; and

and ſo much weight of Air every ſquare inch of the Earth's ſurface ſuſtains; and every ſquare foot 144 times as much, becauſe it contains 144 ſquare inches. Now, as the Earth's ſurface contains, in round numbers, 200,000,000 ſquare miles, it muſt contain no leſs than 5,575,680,000,000,000 ſquare feet; which being multiplied by 2160, the number of pounds on each ſquare foot, amounts to 12,043,468,800,000,000,000 pounds, for the weight of the whole Atmoſphere. At this rate, a middle-ſized man, whoſe ſurface is about 15 ſquare feet, is preſſed by 32,400 pound weight of Air all around; for fluids preſs equally up and down, and on all ſides. But, becauſe this enormous weight is equal on all ſides, and counter-balanced by the ſpring of the Air diffuſed through all parts of our bodies, it is not in the leaſt degree felt by us.

176. Oftentimes the ſtate of the Air is ſuch, that we feel ourſelves languid and dull; which is commonly thought to be occaſioned by the Air's being foggy and heavy about us. But that the Air is then too light, is evident from the mercury's ſinking in the barometer, at which time it is generally found that the Air has not ſufficient ſtrength to bear up the Vapours which compoſe the Clouds: for, when it is otherwiſe, the Clouds mount high, and the Air is more elaſtic and weighty about us, by which means it balances the internal ſpring of the Air within us, braces up our blood-veſſels and nerves, and makes us briſk and lively. A common miſtake about the weight of the Air.

177. According to * Dr. Keill, and other aſtronomical writers, it is entirely owing to the Atmoſphere that the Heavens appear bright in the day-time. For, without an Atmoſphere, only that part of the Heavens would ſhine in which the Sun was placed: and if we could live without Air, and ſhould turn our backs towards the Sun, the whole Heavens would appear as dark as in the night, Without an Atmoſphere the Heavens would always appear dark, and we ſhould have no twilight.

* See his Aſtronomy, p. 232.

PLATE II. night, and the Stars would be ſeen as clear as in the nocturnal ſky. In this caſe, we ſhould have no twilight; but a ſudden tranſition from the brighteſt ſunſhine to the blackeſt darkneſs immediately after ſun-ſet; and from the blackeſt darkneſs to the brighteſt ſun-ſhine at ſun riſing; which would be extremely inconvenient, if not blinding, to all mortals. But, by means of the Atmoſphere, we enjoy the Sun's light, reflected from the aerial particles, for ſome time before he riſes and after he ſets. For, when the Earth by it's rotation has withdrawn the Sun from our ſight, the Atmoſphere being ſtill higher than we, has his light imparted to it; which gradually decreaſes until he has got 18 degrees below the Horizon; and then, all that part of the Atmoſphere which is above us is dark. From the length of twilight, the Doctor has calculated the height of the Atmoſphere (ſo far as it is denſe enough to reflect any light) to be about 44 miles. But it is ſeldom denſe enough at two miles height to bear up the Clouds.

It brings the Sun in view before he riſes, and keeps him in view after he ſets.

178. The Atmoſphere refracts the Sun's rays ſo, as to bring him in ſight every clear day, before he riſes in the Horizon; and to keep him in view for ſome minutes after he is really ſet below it. For, at ſome times of the year, we ſee the Sun ten minutes longer above the Horizon than he would be if there were no refractions: and about ſix minutes every day at a mean rate.

Fig. IX.

179. To illuſtrate this, let *IEK* be a part of the Earth's ſurface, covered with the Atmoſphere *HGFC*; and let *HEO* be the * ſenſible Horizon of an obſerver at *E*. When the Sun is at *A*, really below the Horizon, a ray of light *AC* proceeding from him comes ſtraight to *C*, where it falls on the ſurface of the Atmoſphere, and there entering a denſer medium, it is turned out of it's rectilineal

* As far as one can ſee round him on the Earth.

courſe

course *ACdG*, and bent down to the observer's eye at *E*; who then sees the Sun in the direction of the refracted ray *Ede*, which lies above the Horizon, and being extended out to the Heavens, shews the Sun at *B*, § 171.

180. The higher the Sun rises, the less his rays are refracted, because they fall less obliquely on the surface of the Atmosphere, § 172. Thus, when the Sun is in the direction of the line *EfL* continued, he is so nearly perpendicular to the surface of the Earth at *E*, that his rays are but very little bent from a rectilineal course.

181. The Sun is about $32\frac{1}{4}$ min. of a deg. in breadth, when at his mean distance from the Earth; and the horizontal refraction of his rays is $33\frac{3}{4}$ min. which being more than his whole diameter, brings all his Disc in view, when his uppermost edge rises in the Horizon. At ten deg. height the refraction is not quite 5 min.; at 20 deg. only 2 min. 26 sec.; at 30 deg. but 1 min. 32 sec.; between which and the Zenith, it is scarce sensible: the quantity throughout, is shewn by the annexed table, calculated by Sir Isaac Newton.

The quantity of Refraction.

182. *A*

182. *A* Table *shewing the Refractions of the Sun, Moon, and Stars; adapted to their apparent Altitudes.*

Appar. Alt. D.	Appar. Alt. M.	Refraction M.	Refraction S.	Ap. Alt. D.	Refraction M.	Refraction S.	Ap. Alt. D.	Refraction M.	Refraction S.
0	0	33	45	21	2	18	56	0	36
0	15	30	24	22	2	11	57	0	35
0	30	27	35	23	2	5	58	0	34
0	45	25	11	24	1	59	59	0	32
1	0	23	7	25	1	54	60	0	31
1	15	21	20	26	1	49	61	0	30
1	30	19	40	27	1	44	62	0	28
1	45	18	22	28	1	40	63	0	27
2	0	17	8	29	1	36	64	0	26
2	30	15	2	30	1	32	65	0	25
3	0	13	20	31	1	28	66	0	24
3	30	11	57	32	1	25	67	0	23
4	0	10	48	33	1	22	68	0	22
4	30	9	50	34	1	19	69	0	21
5	0	9	2	35	1	16	70	0	20
5	30	8	21	36	1	13	71	0	19
6	0	7	45	37	1	11	72	0	18
6	30	7	14	38	1	8	73	0	17
7	0	6	47	39	1	6	74	0	16
7	30	6	22	40	1	4	75	0	15
8	0	6	0	41	1	2	76	0	14
8	30	5	40	42	1	0	77	0	13
9	0	5	22	43	0	58	78	0	12
9	30	5	6	44	0	56	79	0	11
10	0	4	52	45	0	54	80	0	10
11	0	4	27	46	0	52	81	0	9
12	0	4	5	47	0	50	82	0	8
13	0	3	47	48	0	48	83	0	7
14	0	3	31	49	0	47	84	0	6
15	0	3	17	50	0	45	85	0	5
16	0	3	4	51	0	44	86	0	4
17	0	2	53	52	0	42	87	0	3
18	0	2	43	53	0	40	88	0	2
19	0	2	34	54	0	39	89	0	1
20	0	2	2[illegible]	55	0	38	90	0	0

183. In all observations, to have the true altitude of the Sun, Moon, or Stars, the refraction must be subtracted from the observed altitude. But the quantity of refraction is not always the same at the same altitude; because heat diminishes the Air's refractive power and density, and cold increases both; and therefore no one table can serve precisely for the same place at all seasons, nor even at all times of the same day; much less for different climates: it having been observed that the horizontal refractions are near a third part less at the Equator than at *Paris*, as mentioned by Dr. SMITH in the 370th remark on his Optics, where the following account is given of an extraordinary refraction of the Sun-beams by cold. "There is a famous observation of this kind made by some *Hollanders* that wintered in *Nova Zembla* in the year 1596, who were surprized to find, that after a continual night of three months, the Sun began to rise seventeen days sooner than according to computation, deduced from the Altitude of the Pole observed to be 76°: which cannot otherwise be accounted for, than by an extraordinary quantity of refraction of the Sun's rays, passing through the cold dense air in that climate. KEPLER computes that the Sun was almost five degrees below the Horizon when he first appeared; and consequently the refraction of his rays was about nine times greater than it is with us."

PLATE II.

The inconstancy of Refractions.

A very remarkable case concerning refraction.

184. The Sun and Moon appear of an oval figure, as *FCGD*, just after their rising, and before their setting: the reason is, that the refraction being greater in the Horizon than at any distance above it, the lowermost limb *G* appears more elevated than the uppermost. But although the refraction shortens the vertical Diameter *FG*, it has no sensible effect on the horizontal Diameter *CD*, which is all equally elevated. When the refraction is so small as to be imperceptible, the Sun and Moon appear perfectly round, as *AEBF*.

Fig. X.

185.

Our imagination cannot judge rightly of the distance of inaccessible objects.

185. We daily observe, that the objects which appear most distinct are generally those which are nearest to us; and consequently, when we have nothing but our imagination to assist us in estimating of distances, bright objects seem nearer to us than those which are less bright, or than the same objects do when they appear less bright and worse defined, even though their distance in both cases be the same. And if in both cases they are seen under the same Angle *, our imagination naturally

PLATE II. Fig. V.

* An Angle is the inclination of two right lines, as *IH* and *KH*, meeting in a point at *H*; and in describing an Angle by three letters, the middle letter always denotes the angular point: thus, the above lines *IH* and *KH* meeting each other at *H*, make the Angle *IHK*. And the point *H* is supposed to be the center of a Circle, the circumference of which contains 360 equal parts, called Degrees. A fourth part of a Circle, called a Quadrant, as *GE*, contains 90 degrees; and every Angle is measured by the number of degrees in the Arc it cuts off; as the Angle *EHP* is 45 degrees, the Angle *EHF* 33, &c. and so the Angle *EHF* is the same with the Angle *CHN*, and also with the Angle *AHM*, because they all cut off the same Arc or portion of the Quadrant *EG*; and so likewise the Angle *EHF* is greater than the Angle *CHD* or *AHL*, because it cuts off a greater Arc.

The nearer an object is to the eye, the bigger it appears, and under the greater Angle is it seen. To illustrate this a little, suppose an Arrow in the position *IK*, perpendicular to the right line *HA* drawn from the eye at *H* through the middle of the Arrow at *O*. It is plain that the Arrow is seen under the Angle *IHK*, and that *HO*, which is it's distance from the eye, divides into halves both the Arrow and the Angle under which it is seen; *viz.* the Arrow into *IO* *OK* and the Angle into *IHO* and *KHO*: and this will be the case whatever distance the Arrow is placed at. Let now three Arrows, all of the same length with *IK*, be placed at the distances *HA*, *HC*, *HE*, still perpendicular to, and bisected by the right line *HA*; then will *AB*, *CD*, *EF*. be each equal to, and represent *IO*; and *AB* (the same as *IO*) will be seen from *H* under the Angle *AHB*; but *CD* (the same as *IO*) will be seen under the Angle *CHD* or *AHL*; and *EF* the same as *IO*) will be seen under the Angle *EHF*, or *CHN*, or *AHM*. Also, *EF* or *IO* at the distance *HE* will appear as long as *CN* would at the distance *HC*, or as *AM* would at the distance *HA*; and *CD* or *IO* at the distance *HC* will appear as long as *AL* would at the distance *HA*.

rally ſuggeſts an idea of a greater diſtance between us and thoſe objects which appear fainter and worſe defined than thoſe which appear brighter under the ſame Angles; eſpecially if they be ſuch objects as we were never near to, and of whoſe real Magnitudes we can be no judges by ſight.

186. But, it is not only in judging of the different apparent Magnitudes of the ſame objects, which are better or worſe defined by their being more or leſs bright, that we may be deceived: for we may make a wrong concluſion even when we view them under equal degrees of brightneſs, and under equal Angles; although they be objects whoſe bulks we are generally acquainted with, ſuch as houſes or trees: for proof of which, the two following inſtances may ſuffice. Nor always of thoſe which are acceſſible.

Firſt, When a houſe is ſeen over a very broad river by a perſon ſtanding on low ground, who ſees nothing of the river, nor knows of it beforehand; the breadth of the river being hid from him, becauſe the banks ſeem contiguous, he loſes the idea of a diſtance equal to that breadth; and the houſe ſeems ſmall, becauſe he refers it to a leſs diſtance than it really is at. But, if he goes to a place from which the river and interjacent ground can be ſeen, though no farther from the houſe, he then perceives the houſe to be at a greater diſtance than he imagined; and therefore fancies it to be bigger than he did at firſt; although in both caſes it appears under the ſame Angle, and conſequently makes no bigger picture on the retina of his eye in the latter caſe than it did in the former. Many have been deceived, by taking a red coat of arms, fixed upon the iron gate in *Clare Hall* walks at The reaſon aſſigned.

HA. So that as an object approaches the eye, both it's Magnitude and the Angle under which it is ſeen increaſe; and as the object recedes, the contrary.

PLATE II. *Cambridge*, for a brick houſe at a much greater diſtance *.

Secondly, In foggy weather, at firſt ſight, we generally imagine a ſmall houſe, which is juſt at hand, to be a great caſtle at a diſtance; becauſe it appears ſo dull and ill defined when ſeen through the Miſt, that we refer it to a much greater diſtance than it really is at; and therefore, under the ſame Angle, we judge it to be much bigger. For, the near object *FE*, ſeen by the eye *ABD*, appears under the ſame Angle *GCH*, that the remote object *GHI* does: and the rays *GFCN* and *HECM* croſſing one another at *C* in the pupil of the eye, limit the ſize of the picture *MN* on the retina; which is the picture of the object *FE*, and if *FE* were taken away, would be the picture of the object *GHI*, only worſe defined; becauſe *GHI*, being farther off, appears duller and fainter than *FE* did. But when a Fog, as *KL*, comes between the eye and the object *FE*, it appears dull and ill defined like *GHI*; which cauſes our imagination to refer *FE* to the greater diſtance *CH*, inſtead of the ſmall diſtance *CE* which it really is at. And conſequently, as miſ-judging the diſtance does not in the leaſt diminiſh the Angle under which the object appears, the ſmall hay-rick *FE* ſeems to be as big as *GHI*.

Fig. XII.

* The fields which are beyond the gate riſe gradually till they are juſt ſeen over it; and the arms, being red, are often miſtaken for a houſe at a conſiderable diſtance in thoſe fields.

I once met with a curious deception in a gentleman's garden at *Hackney*, occaſioned by a large pane of glaſs in the garden-wall at ſome diſtance from his houſe. The glaſs (through which the fields and ſky were diſtinctly ſeen) reflected a very faint image of the houſe; but the image ſeemed to be in the Clouds near the Horizon, and at that diſtance looked as if it were a huge caſtle in the Air. Yet, the Angle under which the image appeared, was equal to that under which the houſe was ſeen: but the image being mentally referred to a much greater diſtance than the houſe, appeared much bigger to the imagination.

187. The

187. The Sun and Moon appear bigger in the Horizon than at any conſiderable height above it. These Luminaries, although at great diſtances from the Earth, appear floating, as it were, on the ſurface of our Atmoſphere *HGFfeC*, a little way beyond the Clouds; of which, thoſe about *F*, directly over our heads at *E*, are nearer us than thoſe about *H* or *e* in the Horizon *HEe*. Therefore, when the Sun or Moon appear in the Horizon at *e*, they are not only ſeen in a part of the Sky which is really farther from us than if they were at any conſiderable Altitude, as about *f*; but they are alſo ſeen through a greater quantity of Air and Vapours at *e* than at *f*. Here we have two concurring appearances which deceive our imagination, and cauſe us to refer the Sun and Moon to a greater diſtance at their riſing or ſetting about *e*, than when they are conſiderably high, as at *f*: firſt, their ſeeming to be on a part of the Atmoſphere at *e*, which is really farther than *f* from a ſpectator at *E*; and ſecondly, their being ſeen through a groſſer medium when at *e* than when at *f*; which, by rendering them dimmer, cauſes us to imagine them to be at a yet greater diſtance. And as, in both caſes, they are ſeen * much under the ſame Angle, we naturally judge them to be biggeſt when they ſeem fartheſt from us; like the above-mentioned houſe, § 186, ſeen from a higher ground, which ſhewed it to be farther off than it appeared from low ground; or the hay-rick, which appeared at a greater diſtance by means of an interpoſing Fog.

PLATE II. Fig. IX.

Why the Sun and Moon appear biggeſt in the Horizon.

188. Any one may ſatisfy himſelf that the Moon appears under no greater Angle in the Horizon than on the Meridian, by taking a large ſheet of paper, and rolling it up in the form of a Tube, of ſuch a width, that obſerving the Moon through

Their apparent Diameters are not leſs on the Meridian than in the Horizon.

* The Sun and Moon ſubtend a greater Angle on the Meridian than in the Horizon, being nearer the Obſerver's Place in the former caſe than in the latter.

it when ſhe riſes, ſhe may, as it were, juſt fill the Tube; then tie a thread round it to keep it of that ſize; and when the Moon comes to the Meridian, and appears much leſs to the eye, look at her again through the ſame Tube, and ſhe will fill it juſt as much, if not more, than ſhe did at her riſing.

189. When the full Moon is in *perigeo*, or at her leaſt diſtance from the Earth, ſhe is ſeen under a larger Angle, and muſt therefore appear bigger than when ſhe is Full at other times: and if that part of the Atmoſphere where ſhe riſes be more replete with Vapours than uſual, ſhe appears ſo much the dimmer; and therefore we fancy her to be ſtill the bigger, by referring her to an unuſually great diſtance; knowing that no objects which are very far diſtant can appear big unleſs they be really ſo.

CHAP. IX.

The Method of finding the Diſtances of the Sun, Moon, and Planets.

190. THOSE who have not learnt how to take the * Altitude of any Celeſtial Phenomenon by a common Quadrant, nor know any

* The Altitude of any celeſtial Phenomenon is an arc of the Sky intercepted between the Horizon and the Phenomenon. In Fig. VI. of Plate II. let *HOX* be a horizontal line, ſuppoſed to be extended from the eye at *A* to *X*, where the Sky and Earth ſeem to meet at the end of a long and level plain; and let *S* be the Sun. The arc *XY* will be the Sun's height above the Horizon at *X*, and is found by the inſtrument *ECD*, which is a quadrantal board, or plate of metal, divided into 90 equal parts or degrees on it's limb *DPC*; and has a couple of little braſs plates, as *a* and *b*, with a ſmall hole in each of them, called *Sight-Holes*, for looking through, parallel to the edge of the Quadrant whereon they ſtand. To the center *E* is fixed one end of a thread *F*, called *the Plumb-Line*, which has a ſmall weight or plummet *P* fixed to its other end. Now, if an obſerver holds the Quadrant upright, without inclining it to either

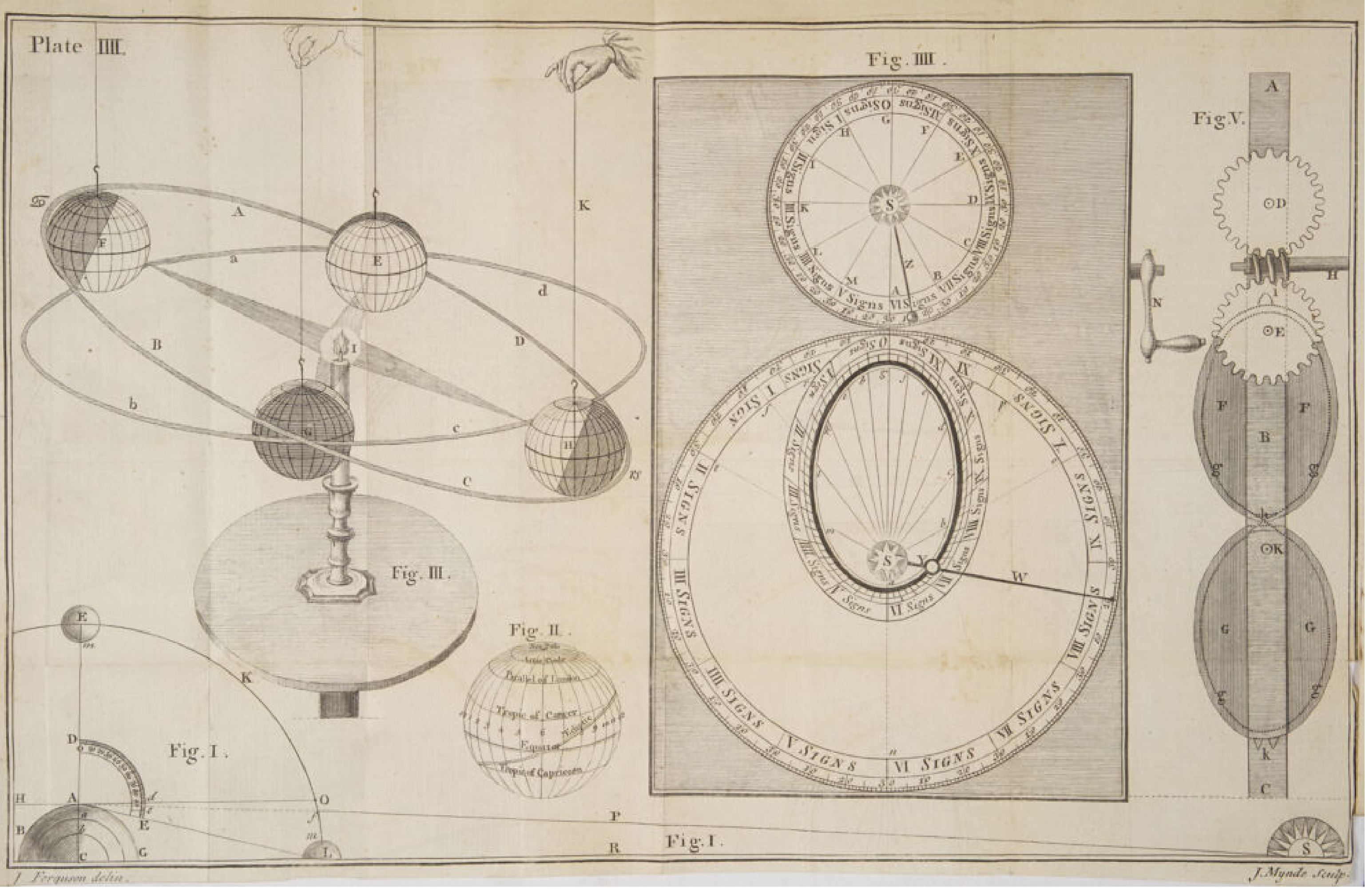


Plate IIII.
Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
Fig. I.
Tropic of Cancer
Equator
Tropic of Capricorn
Parallel of London
Arctic Circle
I SIGN
II SIGNS
III SIGNS
IIII SIGNS
V SIGNS
VI SIGNS
VII SIGNS
VIII SIGNS
IX SIGNS
X SIGNS
XI SIGNS
J. Ferguson delin.
J. Mynde Sculp.

any thing of Plain Trigonometry, may paſs over the firſt Article of this ſhort Chapter, and take the Aſtronomer's word for it, that the diſtances of the Sun and Planets are as ſtated in the firſt Chapter of this Book. But, to every one who knows how to take the Altitude of the Sun, the Moon, or a Star, and can ſolve a plain right-angled Triangle, the following method of finding the diſtances of the Sun and Moon will be eaſily underſtood. PLATE IV.

Let *BAG* be one half of the Earth, *AC* it's ſemi-diameter, *S* the Sun, *m* the Moon, and *EKOL* a quarter of the Circle deſcribed by the Moon in revolving from the Meridian to the Meridian again. Let *CRS* be the rational Horizon of an obſerver at *A*, extended to the Sun in the Heavens; and *HAO* his ſenſible Horizon, extended to the Moon's Orbit. *ALC* is the angle under which the Earth's ſemi-diameter *AC* is ſeen from the Moon at *L*, which is equal to the Angle *OAL*, becauſe the right lines *AO* and *CL* which include both theſe Angles are parallel. *ASC* is the Angle Fig. I.

either ſide, and ſo that the Horizon at *X* is ſeen through the ſight-holes *a* and *b* the plumb-line will cut or hang over the beginning of the degrees at o, in the edge *EC*; but if he elevates the Quadrant ſo as to look through the ſight-holes at any part of the Heavens, ſuppoſe to the Sun at *S*; juſt ſo many degrees as he elevates the ſight-hole *b* above the horizontal line *HOX*, ſo many degrees will the plumb-line cut in the limb *CP* of the Quadrant. For, let the obſerver's eye at *A* be in the center of the celeſtial Arc *XYV* (and he may be ſaid to be in the center of the Sun's apparent diurnal Orbit, let him be on what part of the Earth he will) in which Arc the Sun is at that time, ſuppoſe 25 degrees high, and let the obſerver hold the Quadrant ſo that he may ſee the Sun through the ſight-holes; the plumb-line freely playing on the Quadrant will cut the 25th degree in the limb *CP*, equal to the number of degrees of the Sun's Altitude at the time of obſervation. *N. B.* Whoever looks at the Sun, muſt have a ſmoked glaſs before his eyes to ſave them from hurt. The better way is not to look at the Sun through the ſight-holes, but to hold the Quadrant facing the eye, at a little diſtance, and ſo that the Sun ſhining through one hole, the ray may be ſeen to fall on the other.

 under

under which the Earth's ſemi-diameter *AC* is ſeen from the Sun at *S*, and is equal to the Angle *OAf*, becauſe the lines *AO* and *CKS* are parallel. Now, it is found by obſervation, that the Angle *OAL* is much greater than the Angle *OAf*; but *OAL* is equal to *ALC*, and *OAf* is equal to *ASC*. Now, as *ASC* is much leſs than *ALC*, it proves that the Earth's ſemi-diameter *AC* appears much greater as ſeen from the Moon at *L*, than from the Sun at *S*; and therefore the Earth is much farther from the Sun than from the Moon *. The Quantities of theſe Angles are determined by obſervation in the following manner.

Let a graduated inſtrument, as *DAE* (the larger the better) having a moveable Index with Sight-holes, be fixed in ſuch a manner, that it's plane ſurface may be parallel to the Plane of the Equator, and it's edge *AD* in the Meridian: ſo that when the Moon is in the Equinoctial, and on the Meridian *ADE*, ſhe may be ſeen through the ſight-holes when the edge of the moveable index cuts the beginning of the diviſions at o, on the graduated limb *DE*; and when ſhe is ſo ſeen, let the *preciſe* time be noted. Now, as the Moon revolves about the Earth from the Meridian to the Meridian again in 24 hours 48 minutes, ſhe will go a fourth part round it in a fourth part of that time, *viz.* in 6 hours 12 minutes, as ſeen from *C*, that is, from the Earth's center or Pole. But as ſeen from *A*, the obſerver's place on the Earth's ſurface, the Moon will ſeem to have gone a quarter round the Earth when ſhe comes to the ſenſible Horizon at *O*; for the Index through the ſights of which ſhe is then viewed will be at *d*, 90 degrees from *D*, where it was when ſhe was ſeen at *E*. Now, let the exact moment when the Moon is ſeen at *O* (which will be when ſhe is in or near

* See the Note on § 185.

the

the ſenſible Horizon) be carefully noted *, that it may be known in what time ſhe has gone from *E* to *O*; which time ſubtracted from 6 hours 12 minutes (the time of her going from *E* to *L*) leaves the time of her going from *O* to *L*, and affords an eaſy method for finding the Angle *OAL* (called *the Moon's horizontal Parallax*, which is equal to the Angle *ALC*) by the following Analogy: As the time of the Moon's deſcribing the Arc *EO* is to 90 degrees, ſo is 6 hours 12 minutes to the degrees of the Arc *DdE*, which meaſures the Angle *EAL*; from which ſubtract 90 degrees, and there remains the Angle *OAL*, equal to the Angle *ALC*, under which the Earth's ſemi-diameter *AC* is ſeen from the Moon. Now, ſince all the Angles of a right-lined Triangle are equal to 180 degrees, or to two right Angles, and the ſides of a Triangle are always proportional to the Sines of the oppoſite Angles, ſay, by the *Rule of Three*, as the Sine of the Angle *ALC* at the Moon *L* is to it's oppoſite ſide *AC*, the Earth's ſemi-diameter, which is known to be 3985 miles, ſo is Radius, *viz.* the Sine of 90 degrees, or of the right Angle *ACL*, to it's oppoſite ſide *AL*, which is the Moon's diſtance at *L* from the obſerver's place at *A* on the Earth's ſurface; or, ſo is the Sine of the Angle *CAL* to it's oppoſite ſide *CL*, which is the Moon's diſtance from the Earth's center, and comes out at a mean rate to be 240,000 miles. The Angle *CAL* is equal to what *OAL* wants of 90 degrees.

The Moon's horizontal Parallax, what.

The Moon's diſtance determined.

191. The Sun's diſtance from the Earth is found the ſame way, but with much greater difficulty; becauſe his horizontal Parallax, or the Angle *OAS* equal to the Angle *ASC*, is ſo ſmall, as to be hardly perceptible, being only 10 ſeconds of a minute, or the 360th part of a degree. But

The Sun's diſtance cannot be yet ſo exactly determined as the Moon's.

* Here proper allowance muſt be made for the Refraction, which being about 34 minutes of a degree in the Horizon, will cauſe the Moon's center to appear 34 minutes above the Horizon when her center is really in it.

the Moon's horizontal Parallax, or Angle *OAL* equal to the Angle *ALC*, is very discernible, being 57′ 49″, or 3469″ at it's mean state; which is more than 340 times as great as the Sun's: and therefore, the distances of the heavenly bodies being inversely as the Tangents of their horizontal Parallaxes, the Sun's distance from the Earth is at least 340 times as great as the Moon's; and is rather under-rated at 81 millions of miles, when the Moon's distance is certainly known to be 240 thousand. But because, according to some Astronomers, the Sun's horizontal Parallax is 11 seconds, and according to others only 10, the former Parallax making the Sun's distance to be about 75,000,000 of miles, and the latter 82,000,000; we may take it for granted, that the Sun's distance is not less than as deduced from the former, nor more than as shewn by the latter: and every one who is accustomed to make such observations, knows how hard it is, if not impossible, to avoid an error of a second; especially on account of the inconstancy of horizontal Refractions. And here, the error of one second, in so small an Angle, will make an error of 7 millions of miles in so great a distance as that of the Sun's. But Dr. HALLEY has shewn us how the Sun's distance from the Earth, and consequently the distances of all the Planets from the Sun, may be known to within a 500th part of the whole, by a Transit of Venus over the Sun's Disc, which will happen on the 6th of *June*, in the year 1761; till which time we must content ourselves with allowing the Sun's distance to be about 81 millions of miles, as commonly stated by Astronomers.

How near the truth it may soon be determined.

192. The Sun and Moon appear much about the same bulk: And every one who understands Geometry, knows how their true bulks may be deduced from the apparent, when their real distances are known. Spheres are to one another as the Cubes of their Diameters; whence, if the Sun be

The Sun proved to be much bigger than the Moon.

be 81 millions of miles from the Earth, to appear as big as the Moon, whose distance does not exceed 240 thousand miles, he must, in solid bulk, be 42 millions 875 thousand times as big as the Moon.

193. The horizontal Parallaxes are best observed at the Equator; 1. Because the heat is so nearly equal every day, that the Refractions are almost constantly the same. 2. Because the parallactic Angle is greater there, as at *A* (the distance from thence to the Earth's Axis being greater) than upon any parallel of Latitude, as *a* or *b*.

The relative distances of the Planets from the Sun are known to great precision, though their real distances are not well known.

194. The Earth's distance from the Sun being determined, the distances of all the other Planets from him are easily found by the following analogy, their periods round him being ascertained by observation. As the square of the Earth's period round the Sun is to the cube of it's distance from him, so is the square of the period of any other Planet to the cube of it's distance, in such parts or measures as the Earth's distance was taken; see § 111. This proportion gives us the relative mean distances of the Planets from the Sun to the greatest degree of exactness; and they are as follows, having been deduced from their periodical times, according to the law just mentioned, which was discovered by Kepler, and demonstrtaed by Sir Isaac Newton.

Periodical Revolution to the same fixed Star in days and decimal parts of a day.

Mercury	Venus	The Earth	Mars	Jupiter	Saturn
87.9692	224.6176	365.2564	686.9785	4332.514	10759.275

Relative mean distances from the Sun.

38710	72333	100000	152369	520096	954006

From these numbers we deduce, that if the Sun's horizontal Parallax be 10″, the real mean distances of the Planets from the Sun in English miles are

31,742,200	59,313,060	82,000,000	124,942,580	426,478,720	782,284,920

But if the Sun's Parallax be 11″, their distances are no more than

29,032,500	54.238,570	75,000,000	114,276,750	390,034,500	715,504,500

Errors in distance arising from the mistake of 1″ in the Sun's Parallax.

2,709,700	5,074,490	7,000,000	10,665,830	36,444,220	66,780,420

But, from the late Transit of Venus, A. D. 1761, the Sun's Parallax appears to be only 8″$\frac{6}{100}$; *and according to that, their real distances in miles are*

36,668,373	68,518,044	94,725,840	144,588,575	492,665,307	903,690,197.

195. These numbers shew, that although we have the relative distances of the Planets from the Sun to the greatest nicety, yet the best observers could not ascertain their true distances, until the late long wished-for Transit appeared, which we must confess was embarrassed with several difficulties. But there will be another Transit of Venus over the Sun on the third of *June*, 1769, much better suited to this great Problem.—We wish the Sky may be clear at all Places of observation (none of which can well be in *England*) since there will not be such an opportunity again in less than 105 years afterward.

Why the celestial Poles seem to keep still in the same points of the Heavens, notwithstanding the Earth's motion round the Sun.

196. The Earth's Axis produced to the Stars, being carried * parallel to itself during the Earth's annual revolution, describes a circle in the Sphere of the fixed Stars equal to the Orbit of the Earth. But this Orbit, though very large, would seem no bigger than a point if it were viewed from the Stars; and consequently, the circle described in

* By this is meant, that if a line be supposed to be drawn parallel to the Earth's Axis in any part of it's Orbit, the Axis keeps parallel to that line in every other part of it's Orbit: as in Fig. I. of Plate V; where *abcdefgh* represents the Earth's Orbit in an oblique view, and *Ns* the Earth's Axis keeping always parallel to the line *MN*.

the Sphere of the Stars by the Axis of the Earth produced, if viewed from the Earth, muſt appear but as a point; that is, it's diameter appears too little to be meaſured by obſervation: for Dr. BRADLEY has aſſured us, that if it had amounted to a ſingle ſecond, or two at moſt, he ſhould have perceived it in the great number of obſervations he has made, eſpecially upon γ *Dragonis*; and that it ſeemed to him very probable that the annual Parallax of this Star is not ſo great as a ſingle ſecond; and conſequently, that it is above 400 thouſand times farther from us than the Sun. Hence the celeſtial poles ſeem to continue in the ſame points of the Heavens throughout the year; which by no means diſproves the Earth's annual motion, but plainly proves the diſtance of the Stars to be exceeding great.

197. The ſmall apparent motion of the Stars, § 113, diſcovered by that great Aſtronomer, he found to be no ways owing to their annual Parallax (for it came out contrary thereto) but to the Aberration of their light, which can reſult from no known cauſe beſides that of the Earth's annual motion; and as it agrees ſo exactly therewith, it proves beyond diſpute that the Earth has ſuch a motion: for this Aberration compleats all it's various Phenomena every year; and proves that the velocity of ſtar-light is ſuch as carries it through a ſpace equal to the Sun's diſtance from us in 8 minutes 13 ſeconds of time. Hence, the velocity of Light is * 10 thouſand 210 times as great as the Earth's velocity in it's Orbit; which velocity (from what we know already of the Earth's diſtance from the Sun) may be aſſerted to be at leaſt between 57 and 58 thouſand miles every hour: and ſuppoſing it to be 58000, this number multiplied by the 10210, gives 592 million 180 thouſand miles for the hourly motion of Light: which laſt number divided by 3600, the number of ſeconds in an hour, ſhews that Light flies at the rate of more

The amazing velocity of light.

* SMITH's Optics, § 1197.

than

PLATE IV. than 164 thousand miles every second of time, or swing of a common clock pendulum.

CHAP. X.

The Circles of the Globe described. The different lengths of days and nights, and the vicissitudes of seasons, explained. The explanation of the Phenomena of Saturn's Ring concluded. (See § 81 and 82.)

Circles of the Sphere.

198. If the reader be hitherto unacquainted with the principal circles of the Globe, he should now learn to know them; which he may do sufficiently for his present purpose in a quarter of an hour, if he sets the ball of a terrestrial Globe before him, or looks at the Figure of it, wherein these circles are drawn and named. (Fig. II.) The *Equator* is that great circle which divides the northern half of the Earth from the southern. The *Tropics* are lesser circles parallel to the Equator, and each of them is 23½ degrees from it; a degree in this sense being the 360th part of any great circle which divides the Earth into two equal parts. The *Tropic of Cancer* lies on the north side of the Equator, and the *Tropic of Capricorn* on the south. The *Arctic Circle* has the *North Pole* for it's center, and is just as far from the north Pole as the Tropics are from the Equator: and the *Antarctic Circle* (hid by the supposed convexity of the Figure) is just as far from the *South Pole*, every way round it. These Poles are the very north and south points of the Globe: and all other places are denominated *northward* or *southward*, according to the side of the Equator they lie on, and the Pole to which they are nearest. The *Earth's Axis* is a straight line passing through the center of the Earth, perpendicular to the Equator, and terminating in the Poles at it's surface. This, in the real Earth and Planets, is only an imaginary line; but in artificial Globes or Planets it is a wire by which they are supported,

Equator, Tropics, Polar Circles, and Poles. Fig. II.

Earth's Axis.

supported, and turned round in *Orreries*, or ſuch like machines, by wheel-work. The circles 12. 1. 2. 3. 4, &c. are Meridians to all places they paſs through; and we muſt ſuppoſe thouſands more to be drawn, becauſe every place that is ever ſo little to the eaſt or weſt of any other place, has a different Meridian from that other place. All the Meridians meet in the Poles; and whenever the Sun's center is paſſing over any Meridian, in his apparent motion round the Earth, it is mid-day or noon to all places on that Meridian. PLATE IV. Meridians.

199. The *broad Space* lying between the Tropics, like a girdle ſurrounding the Globe, is called the *torrid Zone*, of which the Equator is in the middle, all around. The *Space* between the Tropic of Cancer and Arctic Circle is called the *North temperate Zone*. *That* between the Tropic of Capricorn and the Antarctic Circle, the *South temperate Zone*. And the two *circular Spaces* bounded by the Polar Circles are the two *Frigid Zones*; denominated *north* or *ſouth*, from that Pole which is in the center of the one or the other of them. Zones.

200. Having acquired this eaſy branch of knowledge, the learner may proceed to make the following experiment with his terreſtrial ball; which will give him a plain idea of the diurnal and annual motions of the Earth, together with the different lengths of days and nights, and all the beautiful variety of ſeaſons, depending on thoſe motions.

Take about ſeven feet of ſtrong wire, and bend it into a circular form, as *abcd*, which being viewed obliquely, appears elliptical as in the Figure. Place a lighted candle on a table, and having fixed one end of a ſilk thread *K*, to the north pole of a ſmall terreſtrial Globe *H*, about three inches diameter, cauſe another perſon to hold the wire circle, ſo that it may be parallel to the table, and as high as the flame of the candle *I*, which ſhould be Fig. III. A pleaſant experiment, ſhewing the different lengths of days and nights, and the variety of ſeaſons.

be in or near the center. Then, having twiſted the thread as towards the left hand, that by untwiſting it may turn the Globe round eaſtward, or contrary to the way that the hands of a watch move; hang the Globe by the thread within this circle, almoſt contiguous to it; and as the thread untwiſts, the Globe (which is enlightened half round by the candle as the Earth is by the Sun) will turn round it's Axis, and the different places upon it will be carried through the light and dark Hemiſpheres, and have the appearance of a regular ſucceſſion of days and nights, as our Earth has in reality by ſuch a motion. As the Globe turns, move your hand ſlowly, ſo as to carry the Globe round the candle according to the order of the letters *abcd*, keeping it's center even with the wire circle; and you will perceive, that the candle being ſtill perpendicular to the Equator, will enlighten the Globe from pole to pole in it's whole motion round the circle; and that every place on the Globe goes equally through the light and the dark, as it turns round by the untwiſting of the thread, and therefore has a perpetual Equinox. The Globe thus turning round repreſents the Earth turning round it's Axis; and the motion of the Globe round the candle repreſents the Earth's annual motion round the Sun, and ſhews, that if the Earth's Orbit had no inclination to it's Axis, all the days and nights of the year would be equally long, and there would be no different ſeaſons. But now, deſire the perſon who holds the wire to hold it obliquely in the poſition *ABCD*, raiſing the ſide ♋ juſt as much as he depreſſes the ſide ♑, that the flame may be ſtill in the plane of the circle; and twiſting the thread as before, that the Globe may turn round it's Axis the ſame way as you carry it round the candle; that is, from weſt to eaſt, let the Globe down into the lowermoſt part of the wire circle at ♑, and if the circle be properly inclined, the candle will ſhine perpendicularly

cularly on the Tropic of Cancer, and the *frigid Zone*, lying within the *arctic* or *north polar Circle*, will be all in the light, as in the Figure; and will keep in the light let the Globe turn round it's Axis ever so often. From the Equator to the north polar Circle all the places have longer days and shorter nights; but from the Equator to the south polar Circle just the reverse. The Sun does not set to any part of the north frigid Zone, as shewn by the candle's shining on it, so that the motion of the Globe can carry no place of that Zone into the dark: and at the same time the *south frigid Zone* is involved in darkness, and the turning of the Globe brings none of it's places into the light. If the Earth were to continue in the like part of it's Orbit, the Sun would never set to the inhabitants of the north frigid Zone, nor rise to those of the south. At the Equator it would be always equal day and night; and as places are gradually more and more distant from the Equator, towards the arctic Circle, they would have longer days and shorter nights; whilst those on the south side of the Equator would have their nights longer than their days. In this case there would be continual summer on the north side of the Equator, and continual winter on the south side of it. Summer Solstice.

But as the Globe turns round it's Axis, move your hand slowly forward, so as to carry the Globe from *H* towards *E*, and the boundary of light and darkness will approach towards the north Pole, and recede towards the south Pole; the northern places will go through less and less of the light, and the southern places through more and more of it; shewing how the northern days decrease in length, and the southern days increase, whilst the Globe proceeds from *H* to *E*. When the Globe is at *E*, it is at a mean state between the lowest and highest parts of it's Orbit; the candle is directly over the Equator, the boundary of light Autumnal Equinox.

and

and darkneſs juſt reaches to both the Poles, and all places on the Globe go equally through the light and dark Hemiſpheres, ſhewing that the days and nights are then equal at all places of the Earth, the Poles only excepted; for the Sun is then ſetting to the north Pole, and riſing to the ſouth Pole.

Continue moving the Globe forward, and as it goes through the quarter *A*, the north Pole recedes ſtill farther into the dark Hemiſphere, and the ſouth Pole advances more into the light, as the Globe comes nearer to ♋: and when it comes there at *F*, the candle is directly over the Tropic of Capricorn, the days are at the ſhorteſt, and nights at the longeſt, in the northern Hemiſphere, all the way from the Equator to the arctic Circle; and the reverſe in the ſouthern Hemiſphere from the Equator to the antarctic Circle; within which Circles it is dark to the north frigid Zone, and light to the ſouth.

Winter Solſtice.

Continue both motions, and as the Globe moves through the quarter *B*, the north Pole advances towards the light, and the ſouth Pole recedes towards the dark; the days lengthen in the northern Hemiſphere, and ſhorten in the ſouthern; and when the Globe comes to *G*, the candle will be again over the Equator (as when the Globe was at *E*) and the days and nights will again be equal as formerly: and the north Pole will be juſt coming into the light, the ſouth Pole going out of it.

Vernal Equinox.

Thus we ſee the reaſon why the days lengthen and ſhorten from the Equator to the polar Circles every year; why there is ſometimes no day or night for many turnings of the Earth, within the polar Circles; why there is but one day and one night in the whole year at the Poles; and why the days and nights are equally long all the year round at the

the Equator, which is always equally cut by the circle bounding light and darkneſs. PLATE IV.

201. The inclination of an Axis or Orbit is merely relative, becauſe we compare it with ſome other Axis or Orbit which we conſider as not inclined at all. Thus, our Horizon being level to us, whatever place of the Earth we are upon, we conſider it as having no inclination; and yet, if we travel 90 degrees from that place, we ſhall then have an Horizon perpendicular to the former; but it will ſtill be level to us. And, if this Book be held ſo that the * Circle *ABCD* be parallel to the Horizon, both the Circle *abcd*, and the Thread or Axis *K*, will be inclined to it. But if the Book or Plate be held, ſo that the Thread be perpendicular to the Horizon, then the Orbit *ABCD* will be inclined to the Thread, and the Orbit *abcd* perpendicular to it, and parallel to the Horizon. We generally conſider the Earth's annual Orbit as having no inclination, and the Orbits of all the other Planets as inclined to it, § 20. Remark. Fig. III.

202. Let us now take a view of the Earth in it's annual courſe round the Sun, conſidering it's Orbit as having no inclination; and it's Axis as inclining $23\frac{1}{2}$ degrees from a line perpendicular to the plane of it's Orbit, and keeping the ſame oblique direction in all parts of it's annual courſe; or, as commonly termed, keeping always parallel to itſelf, § 196.

Let *a,b,c,d,e,f,g,h* be the Earth in eight different parts of it's Orbit, equidiſtant from one another; *Ns* it's Axis, *N* it's north Pole, *s* it's ſouth Pole, PLATE V. Fig. I.

* All Circles appear Ellipſes in an oblique view, as is evident by looking obliquely at the rim of a baſon. For the true figure of a Circle can only be ſeen when the eye is directly over it's center. The more obliquely it is viewed, the more elliptical it appears; until the eye be in the ſame plane with it, and then it appears like a ſtraight line.

PLATE V. and *S* the Sun nearly in the center of the Earth's Orbit, § 18. As the Earth goes round the Sun according to the order of the letters *abcd*, &c. it's Axis *Ns* keeps the same obliquity, and is still parallel to the line *MNs*. When the Earth is at *a*, its north Pole inclines towards the Sun *S*, and brings all the northern places more into the light than at any other time of the year. But when the Earth is at *e* in the opposite time of the year, the north Pole declines from the Sun, which occasions the northern places to be more in the dark than in the light; and the reverse at the southern places, as is evident by the Figure, which I have taken from Dr. LONG's Astronomy. When the Earth is either at *c* or *g*, it's Axis inclines not either to or from the Sun, but lies sidewise to him; and then the Poles are in the boundary of light and darkness; and the Sun, being directly over the Equator, makes equal day and night at all places. When the Earth is at *b*, it is half way between the Summer Solstice and Harvest Equinox; when it is at *d*, it is half way from the Harvest Equinox to the Winter Solstice; at *f*, half way from the Winter Solstice to the Spring Equinox; and at *h*, half way from the Spring Equinox to the Summer Solstice.

A concise view of the seasons.

Fig. II. 203. From this oblique view of the Earth's Orbit, let us suppose ourselves to be raised far above it, and placed just over it's center *S*, looking down upon it from it's north Pole; and as the Earth's Orbit differs but very little from a Circle, we shall have it's figure in such a view represented by the Circle *ABCDEFGH*. Let us suppose this Circle to be divided into 12 equal parts, called *Signs*, having their names affixed to them; and each Sign into 30 equal parts, called *Degrees*, numbered 10, 20, 30, as in the outermost Circle of the Figure, which represents the great Ecliptic in the Heavens. The Earth is shewn in eight different positions in this Circle, and in each position *Æ* 's

The seasons shewn in another view of the Earth, and it's Orbit.

8 the

the Equator, *T* the Tropic of Cancer, the *dotted Circle* the parallel of *London*, *U* the arctic or north polar Circle, and *P* the north Pole, where all the Meridians or Hour-Circles meet, § 198. As the Earth goes round the Sun, the north Pole keeps conſtantly towards one part of the Heavens, as it keeps in the Figure towards the right hand ſide of the Plate.

When the Earth is at the beginning of Libra, namely on the 20th of *March*, in this Figure (as at *g* in Fig. I.) the Sun *S* as ſeen from the Earth appears at the beginning of Aries in the oppoſite part of the Heavens *, the north Pole is juſt coming into the light, and the Sun is vertical to the Equator; which, together with the Tropic of Cancer, parallel of *London*, and arctic Circle, are all equally cut by the Circle bounding light and darkneſs, coinciding with the ſix o'clock hour Circle, and therefore the days and nights are equally long at all places: for every part of the Meridian *ÆTLa* comes into the light at ſix in the morning, and revolving with the Earth according to the order of the hour-letters, goes into the dark at ſix in the evening. There are 24 Meridians or Hour-Circles drawn on the Earth in this Figure, to ſhew the time of Sun-riſing and ſetting at different Seaſons of the Year. Vernal Equinox.

As the Earth moves in the Ecliptic according to the order of the letters *ABCD*, &c. through the Signs Libra, Scorpio, and Sagittarius, the north Pole comes more and more into the light; the days increaſe as the nights decreaſe in length, at all places north of the Equator *Æ*; which is plain by viewing the Earth at *b* on the 5th of *May*, when it is in the 15th degree of Scorpio †, and

* Here we muſt ſuppoſe the Sun to be no bigger than an ordinary point (as .) becauſe he only covers a Circle half a degree in diameter in the Heavens; whereas in the Figure he hides a whole ſign at once from the Earth.

† Here we muſt ſuppoſe the Earth to be a much ſmaller point than that in the preceding note marked for the Sun.

PLATE V. Fig. II. the Sun as seen from the Earth appears in the 15th degree of Taurus. For then, the Tropic of Cancer *T* is in the light from a little after five in the morning till almost seven in the evening; the parallel of *London* from half an hour past four till half an hour past seven; the polar Circle *U* from three till nine; and a large track round the north Pole *P* has day all the 24 hours, for many rotations of the Earth on it's Axis.

When the Earth comes to *c*, at the beginning of Capricorn, and the Sun as seen from the Earth appears at the beginning of Cancer, on the 21st of *June*, as in this Figure, it is in the position *a* in Fig. I; and it's north Pole inclines towards the Sun, so as to bring all the north frigid Zone into the light, and the northern parallels of Latitude more into the light than the dark from the Equator to the polar Circle; and the more so as they are farther from the Equator. The Tropic of Cancer is in the light from five in the morning till seven at night, the parallel of *London* from a quarter before four till a quarter after eight; and the polar Circle just touches the dark, so that the Sun has only the lower half of his Disc hid from the inhabitants on that Circle for a few minutes about midnight, supposing no inequalities in the Horizon, and no Refractions.

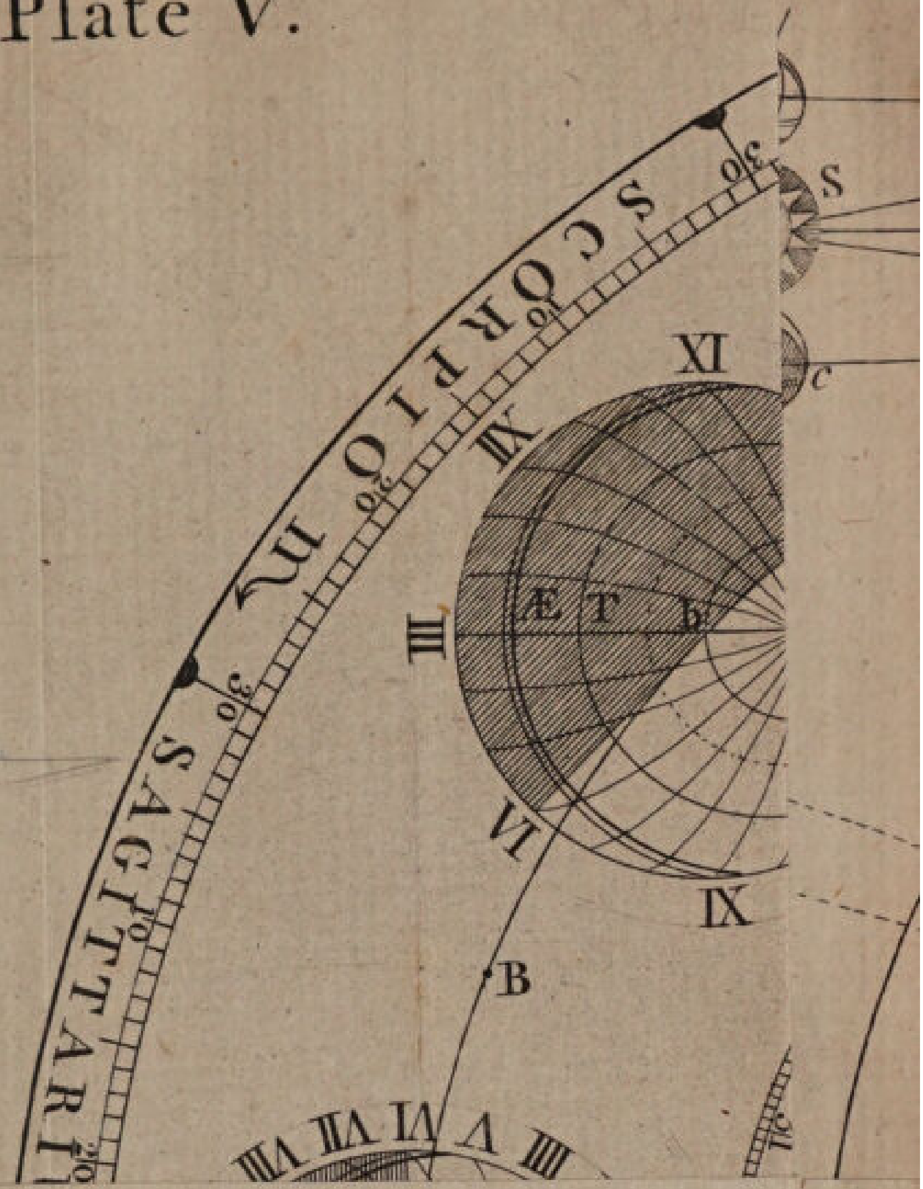
Summer Solstice.

A bare view of the Figure is enough to shew, that as the Earth advances from Capricorn towards Aries, and the Sun appears to move from Cancer towards Libra, the north Pole recedes towards the dark, which causes the days to decrease, and the nights to increase in length, till the Earth comes to the beginning of Aries, and then they are equal as before; for the boundary of light and darkness cuts the Equator and all it's parallels equally, or in halves. The north pole then goes into the dark, and continues therein until the Earth goes half way round it's Orbit; or, from the 23d of *September* till the 20th of *March*. In the middle

Autumnal Equinox.

8 between

Plate V.



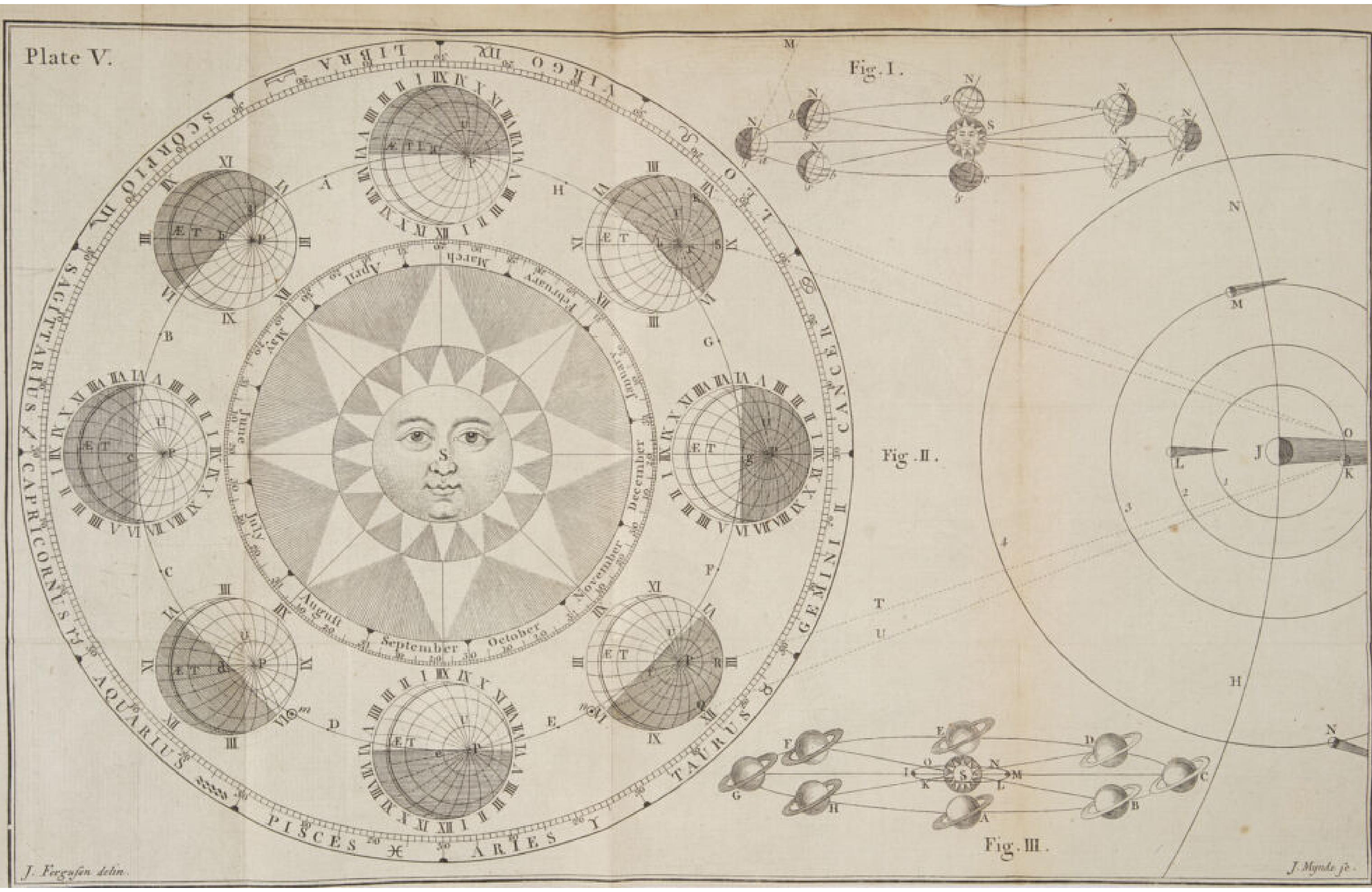


Plate V.
Fig. I.
Fig. II.
Fig. III.
LIBRA
VIRGO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORNUS
SAGITTARIUS
SCORPIO
January
February
March
April
May
June
July
August
September
October
November
December
J. Ferguson delin.
J. Mynde sc.

between these times, *viz.* on the 22d of *December*, the north Pole is as far as it can be in the dark, which is 23½ degrees, equal to the inclination of the Earth's Axis from a perpendicular to it's Orbit: and then, the northern parallels are as much in the dark as they were in the light on the 21st of *June*; the winter nights being as long as the summer days, and the winter days as short as the summer nights. It is needless to enlarge farther on this subject, as we shall have occasion to mention the seasons again in describing the *Orrery*, § 439. Only this must be noted, that all that has been said of the northern Hemisphere, the contrary must be understood of the southern; for on different sides of the Equator the seasons are contrary, because, when the northern Hemisphere inclines towards the Sun, the southern declines from him.

Winter Solstice.

204. As Saturn goes round the Sun, his obliquely posited ring, like our Earth's Axis, keeps parallel to itself, and is therefore turned edgewise to the Sun twice in a Saturnian year, which is almost as long as 30 of our years, § 81. But the ring, though considerably broad, is too thin to be seen by us when it is turned edgewise to the Sun, at which time it is also edgewise to the Earth; and therefore it disappears once in every fifteen years to us. As the Sun shines half a year together on the north Pole of our Earth, then disappears to it, and shines as long on the south Pole; so, during one half of Saturn's year, the Sun shines on the north side of his ring, then disappears to it, and shines as long on it's south side. When the Earth's Axis inclines neither to nor from the Sun, but sidewise to him, he instantly ceases to shine on one Pole, and begins to enlighten the other; and when Saturn's Ring inclines neither to nor from the Sun, but sidewise

The Phenomena of Saturn's Ring.

 to

PLATE V. to him, he ceaſes to ſhine on the one ſide of it, and begins to ſhine upon the other.

Fig. III. Let *S* be the Sun, *ABCDEFGH* Saturn's Orbit, and *IKLMNO* the Earth's Orbit. Both Saturn and the Earth move according to the order of the letters, and when Saturn is at *A* his ring is turned edgewiſe to the Sun *S*, and he is then ſeen from the Earth as if he had loſt his ring, let the Earth be in any part of it's Orbit whatever, except between *N* and *O*; for whilſt it deſcribes that ſpace, Saturn is apparently ſo near the Sun as to be hid in his beams. As Saturn goes from *A* to *C*, his ring appears more and more open to the Earth: at *C* the ring appears moſt open of all; and ſeems to grow narrower and narrower as Saturn goes from *C* to *E*; and when he comes to *E*, the ring is again turned edgewiſe both to the Sun and Earth: and as neither of it's ſides are illuminated, it is inviſible to us, becauſe it's edge is too thin to be perceptible: and Saturn appears again as if he had loſt his ring. But as he goes from *E* to *G*, his ring opens more and more to our view on the under ſide; and ſeems juſt as open at *G* as it was at *C*; and may be ſeen in the night-time from the Earth in any part of it's Orbit, except about *M*, when the Sun hides the Planet from our view. As Saturn goes from *G* to *A*, his ring turns more and more edgewiſe to us, and therefore it ſeems to grow narrower and narrower; and at *A* it diſappears as before. Hence, while Saturn goes from *A* to *E*, the Sun ſhines on the upper ſide of his ring, and the under ſide is dark; and whilſt he goes from *E* to *A*, the Sun ſhines on the under ſide of his ring, and the upper ſide is dark.

It may perhaps be imagined that this Article might have been placed more properly after § 81, than here: but when the candid reader conſiders that all the various Phenomena of Saturn's Ring depend upon a cauſe ſimilar to that of our Earth's

Fig. I. and III. ſeaſons, he will readily allow that they are beſt explained

plained together; and that the two Figures ſerve to illuſtrate each other. PLATE VI.

205. The Earth's Orbit being elliptical, and the Sun conſtantly keeping in it's lower Focus, which is 1,377,000 miles from the middle point of the longer Axis, the Earth comes twice ſo much, or 2,754,000 miles nearer the Sun at one time of the year than at another: for the Sun appearing under a larger Angle in our winter than ſummer, proves that the Earth is nearer the Sun in winter, (*ſee the Note on Art.* 185.) But here, this natural queſtion will ariſe, Why have we not the hotteſt weather when the Earth is neareſt the Sun? In anſwer it muſt be obſerved, that the excentricity of the Earth's Orbit, or 1 million 377 miles bears no greater proportion to the Earth's mean diſtance from the Sun than 17 does to 1000; and therefore, this ſmall difference of diſtance cannot occaſion any great difference of heat or cold. But the principal cauſe of this difference is, that in winter the Sun's rays fall ſo obliquely upon us, that any given number of them is ſpread over a much greater portion of the Earth's ſurface where we live; and therefore each point muſt then have fewer rays than in ſummer. Moreover, there comes a greater degree of cold in the long winter nights, than there can return of heat in ſo ſhort days; and on both theſe accounts the cold muſt increaſe. But in ſummer the Sun's rays fall more perpendicularly upon us, and therefore come with greater force, and in greater numbers on the ſame place; and by their long continuance, a much greater degree of heat is imparted by day than can fly off by night.

The Earth nearer the Sun in winter than in ſummer.

Why the weather is coldeſt when the Earth is neareſt the Sun.

206. That a greater number of rays fall on the ſame place, when they come perpendicularly, than when they come obliquely on it, will appear by the Figure. For, let *AB* be a certain number of the Sun's rays falling on *CD* (which, let us ſuppoſe to be *London*) on the 22d of *June*: but, on Fig. II.

the 22d of *December*, the line *CD*, or *London*, has the oblique position *Cd* to the same rays; and therefore scarce a third part of them falls upon it, or only those between *A* and *e*; all the rest *eB* being expended on the space *dP*, which is more than double the length of *CD* or *Cd*. Besides, those parts which are once heated, retain the heat for some time; which, with the additional heat daily imparted, makes it continue to increase, though the Sun declines towards the south: and this is the reason why *July* is hotter than *June*, although the Sun has withdrawn from the summer Tropic; as we find it is generally hotter at three in the afternoon, when the Sun has gone towards the west, than at noon when he is on the Meridian. Likewise, those places which are well cooled require time to be heated again; for the Sun's rays do not heat even the surface of any body till they have been some time upon it. And therefore we find *January* for the most part colder than *December*, although the Sun has withdrawn from the winter Tropic, and begins to dart his beams more perpendicularly upon us, when we have the position *CF*. An iron bar is not heated immediately upon being put into the fire, nor grows cold till some time after it has been taken out.

CHAP. XI.

The Method of finding the Longitude by the Eclipses of Jupiter's Satellites: The amazing Velocity of Light demonstrated by these Eclipses.

First Meridian, and Longitude of places, what.

207. GEographers arbitrarily choose to call the Meridian of some remarkable place *the first Meridian*. There they begin their reckoning; and just so many degrees and minutes as any other place is to the eastward or westward of that Meridian, so much east or west Longitude they say it has. A degree is the 360th part of a Circle, be it great

great or ſmall; and a minute the 60th part of a degree. The *Engliſh* Geographers reckon the Longitude from the Meridian of the Royal Obſervatory at *Greenwich*, and the *French* from the Meridian of *Paris*. PLATE V.

208. If we imagine twelve great Circles, one of which is the Meridian of any given place, to interſect each other in the two Poles of the Earth, and to cut the Equator *Æ* at every 15th degree, they will be divided by the Poles into 24 Semicircles which divide the Equator into 24 equal parts; and as the Earth turns on it's Axis, the planes of theſe Semicircles come ſucceſſively after one another every hour to the Sun. As in an hour of time there is a revolution of 15 degrees of the Equator, in a minute of time there will be a revolution of 15 minutes of the Equator, and in a ſecond of time a revolution of 15 ſeconds. There are two tables annexed to this Chapter, for reducing mean ſolar time into degrees and minutes of the terreſtrial Equator; and alſo for converting degrees and parts of the Equator into mean ſolar time. Fig. II. Hour Circles. An hour of time equal to 15 degrees of motion:

209. Becauſe the Sun enlightens only one half of the Earth at once, as it turns round it's Axis, he riſes to ſome places at the ſame moments of abſolute Time when he ſets to others; and when it is mid-day to ſome places, it is mid-night to others. The XII on the middle of the Earth's enlightened ſide, next the Sun, ſtands for mid-day; and the oppoſite XII on the middle of the dark ſide, for mid-night. If we ſuppoſe this Circle of hours to be fixed in the plane of the Equinoctial, and the Earth to turn round within it, any particular Meridian will come to the different hours ſo, as to ſhew the true time of the day or night at all places on that Meridian. Therefore,

210. To every place 15 degrees eaſtward from any given Meridian, it is noon an hour ſooner than on that Meridian; becauſe their Meridian comes

to

to the Sun an hour ſooner: and to all places 15 degrees weſtward, it is noon an hour later, § 208, becauſe their Meridian comes an hour later to the Sun; and ſo on: every 15 degrees of motion cauſing an hour's difference of time. Therefore they who have noon an hour later than we, have their Meridian, that is, their Longitude, 15 degrees weſtward from us; and they who have noon an hour ſooner than we, have their Meridian 15 degrees eaſtward from ours: and ſo for every hour's difference of time 15 degrees difference of Longitude. Conſequently, if the beginning or ending of a Lunar Eclipſe be obſerved, ſuppoſe at *London*, to be exactly at mid-night, and in ſome other place at 11 at night, that place is 15 degrees weſtward from the Meridian of *London*: if the ſame Eclipſe be obſerved at one in the morning at another place, that place is 15 degrees eaſtward from the ſaid Meridian.

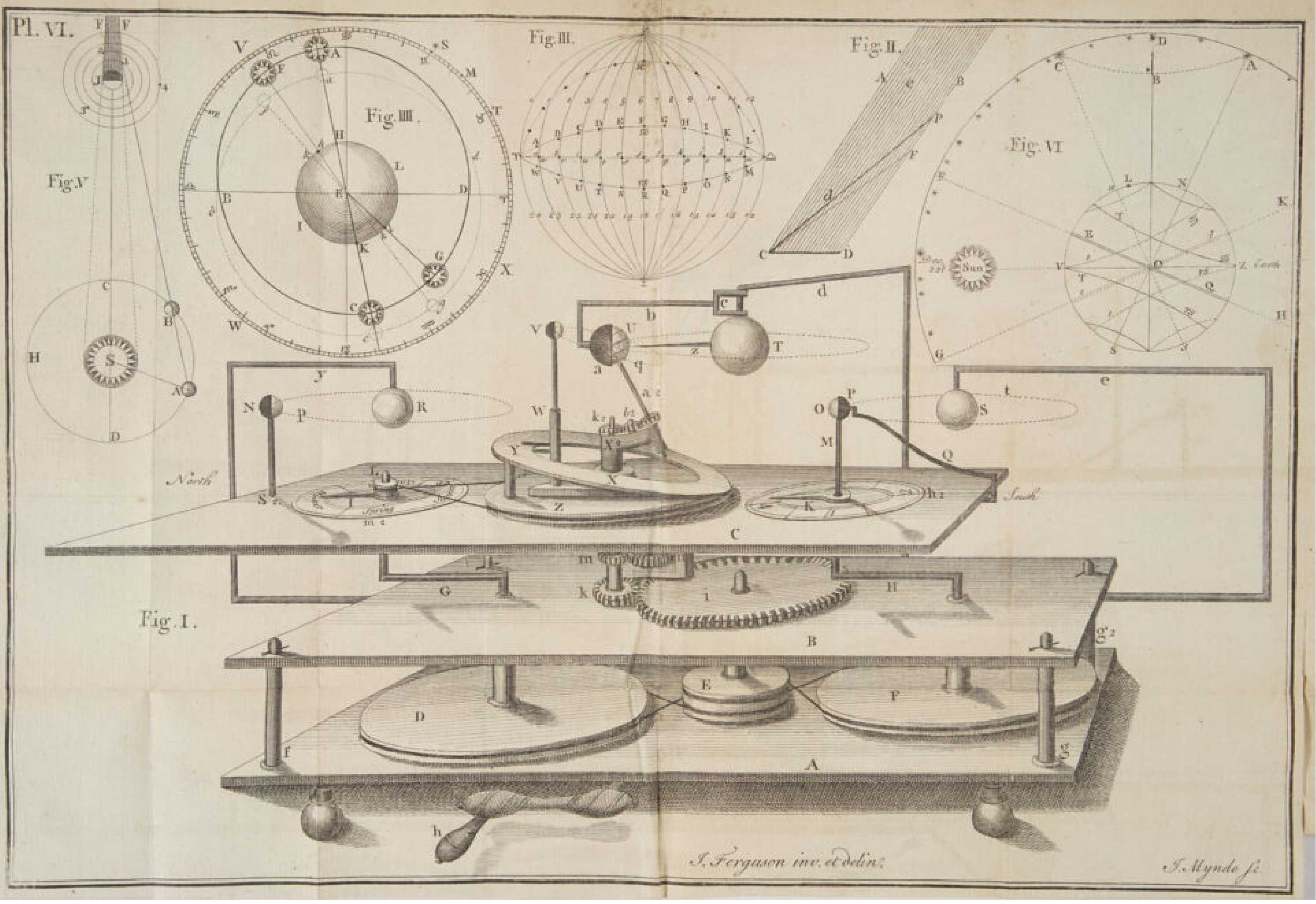
And conſequently to 15 degrees of Longitude.

Lunar Eclipſes uſeful in finding the Longitude.

211. But as it is not eaſy to determine the exact moment either of the beginning or ending of a Lunar Eclipſe, becauſe the Earth's ſhadow through which the Moon paſſes is faint and ill defined about the edges; we have recourſe to the Eclipſes of Jupiter's Satellites, which diſappear ſo inſtantaneouſly as they enter into Jupiter's ſhadow, and emerge ſo ſuddenly out of it, that we may fix the phenomenon to a ſecond of time. The firſt or neareſt Satellite to Jupiter is the moſt advantageous for this purpoſe, becauſe it's motion is quicker than the motion of any of the reſt, and therefore it's immerſions and emerſions are more frequent.

Eclipſes of Jupiter's Satellites much better for that purpoſe.

212. The *Engliſh* Aſtronomers have calculated Tables for ſhewing the times of the Eclipſes of Jupiter's Satellites to great preciſion, for the Meridian of *Greenwich*. Now, let an obſerver, who has theſe Tables with a good Teleſcope and a well-regulated Clock at any other place of the Earth, obſerve the beginning or ending of an Eclipſe of one


Pl. VI.
Fig. V
Fig. IIII.
Fig. III.
Fig. II.
Fig. VI
Fig. I.
North
South
Sun
Earth
Spring
J. Ferguson inv. et delin.
J. Mynde sc.

one of Jupiter's Satellites, and note the precise moment of time that he saw the Satellite, either immerge into, or emerge out of the shadow, and compare that time with the time shewn by the Tables for *Greenwich*; then, 15 degrees difference of Longitude being allowed for every hour's difference of time, will give the Longitude of that place from *Greenwich*, as above, § 210; and if there be any odd minutes of time, for every minute a quarter of a degree, east or west, must be allowed, as the time of observation is later or earlier than the time shewn by the Tables. Such Eclipses are very convenient for this purpose at land, because they happen almost every day; but are of no use at sea, because the rolling of the ship hinders all nice telescopical observations. PLATE V. How to solve this important problem.

213. To explain this by a Figure, let *J* be Jupiter, *K*, *L*, *M*, *N* his four Satellites in their respective Orbits 1, 2, 3, 4; and let the Earth be at *f* (suppose in *November*, although that month is no otherways material than to find the Earth readily in this scheme, where it is shewn in eight different parts of it's Orbit.) Let *Q* be a place on the Meridian of *Greenwich*, and *R* a place on some other Meridian eastward from *Greenwich*. Let a person at *R* observe the instantaneous vanishing of the first Satellite *K* into Jupiter's shadow, suppose at three o'clock in the morning; but by the Tables he finds the immersion of that Satellite to be at mid-night at *Greenwich*: he can then immediately determine, that as there are three hours difference of time between *Q* and *R*, and that *R* is three hours forwarder in reckoning than *Q*, it must be 45 degrees of east Longitude from the Meridian of *Q*. Were this method as practicable at sea as at land, any sailor might almost as easily, and with equal certainty, find the Longitude as the Latitude. Fig. II. Illustrated by an example.

214. Whilst the Earth is going from *C* to *F* in it's Orbit, only the immersions of Jupiter's Satellites Fig. II.

lites

We ſeldom ſee the beginning and end of the ſame Eclipſe of any of Jupiter's Moons.

lites into his ſhadow are generally ſeen; and their emerſions out of it while the Earth goes from *G* to *B*. Indeed, both theſe appearances may be ſeen of the ſecond, third, and fourth Satellite when eclipſed, whilſt the Earth is between *D* and *E*, or between *G* and *A*; but never of the firſt Satellite, on account of the ſmallneſs of it's Orbit and the bulk of Jupiter; except only when Jupiter is directly oppoſite to the Sun; that is, when the Earth is at *g*: and even then, ſtrictly ſpeaking, we cannot ſee either the immerſions or emerſions of any of his Satellites, becauſe his body being directly between us and his conical ſhadow, his Satellites are hid by his body a few moments before they touch his ſhadow; and are quite emerged from thence before we can ſee them, as it were, juſt dropping from him. And when the Earth is at *c*, the Sun, being between it and Jupiter, hides both him and his Moons from us.

In this Diagram, the Orbits of Jupiter's Moons are drawn in true proportion to his diameter; but, in proportion to the Earth's Orbit, they are drawn 81 times too large.

Jupiter's conjunctions with the Sun, or oppoſitions to him, are every year in different parts of the Heavens.

215. In whatever month of the year Jupiter is in conjunction with the Sun, or in oppoſition to him, in the next year it will be a month later at leaſt. For whilſt the Earth goes once round the Sun, Jupiter deſcribes a twelfth part of his Orbit. And therefore, when the Earth has finiſhed it's annual period from being in a line with the Sun and Jupiter, it muſt go as much forwarder as Jupiter has moved in that time, to overtake him again; juſt like the minute-hand of a watch, which muſt, from any conjunction with the hour-hand, go once round the dial-plate and ſomewhat above a twelfth part more, to overtake the hour-hand again.

216. It is found by obſervation, that when the Earth is between the Sun and Jupiter, as at *g*, his Satellites

Satellites are eclipſed about 8 minutes ſooner than they ſhould be according to the Tables: and when the Earth is at *B* or *C*, theſe Eclipſes happen about 8 minutes later than the Tables predict them. Hence it is undeniably certain, that the motion of Light is not inſtantaneous, ſince it takes about 16½ minutes of time to go through a ſpace equal to the diameter of the Earth's Orbit, which is 162 millions of miles in length: and conſequently the particles of Light fly about 164 thouſand 494 miles every ſecond of time, which is above a million of times ſwifter than the motion of a cannon-bullet. And as light is 16½ minutes in travelling acroſs the Earth's Orbit, it muſt be 8¼ minutes in coming from the Sun to us: therefore, if the Sun were annihilated, we ſhould ſee him for 8¼ minutes after; and if he were again created, he would be 8¼ minutes old before we could ſee him.

PLATE VI.

The ſurpriſing velocity of Light.

217. To illuſtrate this progreſſive motion of Light, let *A* and *B* be the Earth in two different parts of it's Orbit, whoſe diſtance from each other is 81 millions of miles, equal to the Earth's diſtance from the Sun *S*. It is plain, that if the motion of Light were inſtantaneous, the Satellite 1 would appear to enter into Jupiter's ſhadow *FF* at the ſame moment of time to a ſpectator in *A* as to another in *B*. But by many years obſervations it has been found, that the immerſion of the Satellite into the ſhadow is ſeen 8¼ minutes ſooner when the Earth is at *B*, than when it is at *A*. And ſo, as Mr. ROMER firſt diſcovered, the motion of Light is thereby proved to be progreſſive, and not inſtantaneous, as was formerly believed. It is eaſy to compute in what time the Earth moves from *A* to *B*; for the Chord of 60 degrees of any Circle is equal to the Semi-diameter of that Circle; and as the Earth goes through all the 360 degrees of it's Orbit in a year, it goes through 60 of thoſe degrees in about 61 days. Therefore,

Fig. V.

Illuſtrated by a Figure.

if on any given day, suppose the first of *June*, the Earth is at *A*, on the first of *August* it will be at *B*: the chord, or straight line *AB*, being equal to *DS* the Radius of the Earth's Orbit, the same with *AS* it's distance from the Sun.

218. As the Earth moves from *D* to *C*, through the side *AB* of it's Orbit, it is constantly meeting the light of Jupiter's Satellites sooner, which occasions an apparent acceleration of their Eclipses: and as it moves through the other half *H* of it's Orbit, from *C* to *D*, it is receding from their light, which occasions an apparent retardation of their Eclipses, because their light is then longer before it overtakes the Earth.

219. That these accelerations of the immersions of Jupiter's Satellites into his shadow, as the Earth approaches towards Jupiter, and the retardations of their emersions out of his shadow, as the Earth is going from him, are not occasioned by any inequality arising from the motions of the Satellites in excentric Orbits, is plain, because it affects them all alike, in whatever parts of their Orbits they are eclipsed. Besides, they go often round their Orbits every year, and their motions are no way commensurate to the Earth's. Therefore, a Phenomenon not to be accounted for from the real motions of the Satellites, but so easily deducible from the Earth's motion, and so answerable thereto, must be allowed to result from it. This affords one very good proof of the Earth's annual motion.

220. TABLES

220. TABLES for converting mean solar TIME into Degrees and Parts of the terrestrial EQUATOR; and also for converting Degrees and Parts of the EQUATOR into mean solar Time.

TABLE I. For converting Time into Degrees and Parts of the Equator.

Hours	Degrees	*Min. | Sec. | Thirds	Deg. | Min. | Sec.	Min. | Sec. | Thirds	*Min. | Sec. | Thirds	Deg. | Min. | Sec.	Min. | Sec. | Thirds
1	15	1	0	15	31	7	45
2	30	2	0	30	32	8	0
3	45	3	0	45	33	8	15
4	60	4	1	0	34	8	30
5	75	5	1	15	35	8	45
6	90	6	1	30	36	9	0
7	105	7	1	45	37	9	15
8	120	8	2	0	38	9	30
9	135	9	2	15	39	9	45
10	150	10	2	30	40	10	0
11	165	11	2	45	41	10	15
12	180	12	3	0	42	10	30
13	195	13	3	15	43	10	45
14	210	14	3	30	44	11	0
15	225	15	3	45	45	11	15
16	240	16	4	0	46	11	30
17	255	17	4	15	47	11	45
18	270	18	4	30	48	12	0
19	285	19	4	45	49	12	15
20	300	20	5	0	50	12	30
21	315	21	5	15	51	12	45
22	330	22	5	30	52	13	0
23	345	23	5	45	53	13	15
24	360	24	6	0	54	13	30
25	375	25	6	15	55	13	45
26	390	26	6	30	56	14	0
27	405	27	6	45	57	14	15
28	420	28	7	0	58	14	30
29	435	29	7	15	59	14	45
30	450	30	7	30	60	15	0

TABLE II. For converting Degrees and Parts of the Equator into Time.

*Deg. | Min. | Sec.	Hours | Min. | Sec.	Min. | Sec. | Thirds	*Deg. | Min. | Sec.	Hours | Min. | Sec.	Min. | Sec. | Thirds	Degrees	Hours	Minutes
1	0	4	31	2	4	70	4	40
2	0	8	32	2	8	80	5	20
3	0	12	33	2	12	90	6	0
4	0	16	34	2	16	100	6	40
5	0	20	35	2	20	110	7	20
6	0	24	36	2	24	120	8	0
7	0	28	37	2	28	130	8	40
8	0	32	38	2	32	140	9	20
9	0	36	39	2	36	150	10	0
10	0	40	40	2	40	160	10	40
11	0	44	41	2	44	170	11	20
12	0	48	42	2	48	180	12	0
13	0	52	43	2	52	190	12	40
14	0	56	44	2	56	200	13	20
15	1	0	45	3	0	210	14	0
16	1	4	46	3	4	220	14	40
17	1	8	47	3	8	230	15	20
18	1	12	48	3	12	240	16	0
19	1	16	49	3	16	250	16	40
20	1	20	50	3	20	260	17	20
21	1	24	51	3	24	270	18	0
22	1	28	52	3	28	280	18	40
23	1	32	53	3	32	290	19	20
24	1	36	54	3	36	300	20	0
25	1	40	55	3	40	310	20	40
26	1	44	56	3	44	320	21	20
27	1	48	57	3	48	330	22	0
28	1	52	58	3	52	340	22	40
29	1	56	59	3	56	350	23	20
30	2	0	60	4	0	360	24	0

These are the Tables mentioned in the 208th Article, and are so easy, that they scarce require any farther explanation than to inform the reader, that if, in Table I. he reckons the columns marked with Asterisks to be minutes of time, the other columns give the equatoreal parts or motion in degrees and minutes; if he reckons the Asterisk columns to be seconds, the others give the motion in minutes and seconds of the Equator; if thirds, in seconds and thirds: And if in Table II. he reckons the Asterisk columns to be degrees of motion, the others give the time answering thereto in hours and minutes; if minutes of motion, the time is minutes and seconds; if seconds of motion, the corresponding time is given in seconds and thirds. An example in each case will make the whole very plain.

EXAMPLE I.

In 10 hours 15 minutes 24 seconds 20 thirds, *Qu.* How much of the Equator revolves through the Meridian?

		Deg.	M.	S.
Hours	10	150	0	0
Min.	15	3	45	0
Sec.	24		6	0
Thirds	20			5
Answer		153	51	5

EXAMPLE II.

In what time will 153 degrees 51 minutes 5 seconds of the Equator revolve through the Meridian?

		H.	M.	S.	T.
Deg.	150	10	0	0	0
Deg.	3		12	0	0
Min.	51		3	24	0
Sec.	5				20
Answer		10	15	24	20

CHAP. XII.

Of Solar and Sydereal Time.

Sydereal days shorter than solar days, and why.

221. THE Stars appear to go round the Earth in 23 hours 56 minutes 4 seconds, and the Sun in 24 hours: so that the Stars gain three minutes 56 seconds upon the Sun every day, which amounts

amounts to one diurnal revolution in a year; and therefore, in 365 days as meaſured by the returns of the Sun to the Meridian, there are 366 days as meaſured by the Stars returning to it: the former are called *Solar Days*, and the latter *Sydereal*. PLATE III.

The diameter of the Earth's Orbit is but a phyſical point in proportion to the diſtance of the Stars; for which reaſon, and the Earth's uniform motion on it's Axis, any given Meridian will revolve from any Star to the ſame Star again in every abſolute turn of the Earth on it's Axis, without the leaſt perceptible difference of time ſhewn by a clock which goes exactly true.

If the Earth had only a diurnal motion, without an annual, any given Meridian would revolve from the Sun to the Sun again in the ſame quantity of time as from any Star to the ſame Star again; becauſe the Sun would never change his place with reſpect to the Stars. But, as the Earth advances almoſt a degree eaſtward in it's Orbit in the time that it turns eaſtward round it's Axis, whatever Star paſſes over the Meridian on any day with the Sun, will paſs over the ſame Meridian on the next day when the Sun is almoſt a degree ſhort of it; that is, 3 minutes 56 ſeconds ſooner. If the year contained only 360 days, as the Ecliptic does 360 degrees, the Sun's apparent place, ſo far as his motion is equable, would change a degree every day; and then the ſydereal days would be juſt 4 minutes ſhorter than the ſolar.

Let *ABCDEFGHIKLM* be the Earth's Orbit, Fig. II. in which it goes round the Sun every year, according to the order of the letters, that is, from weſt to eaſt; and turns round it's Axis the ſame way from the Sun to the Sun again every 24 hours. Let *S* be the Sun, and *R* a fixed Star at ſuch an immenſe diſtance, that the diameter of the Earth's Orbit bears no ſenſible proportion to that diſtance. Let *Nn* be any particular Meridian of the Earth, and *N* a given point or place upon that Meridian.

When the Earth is at *A*, the Sun *S* hides the Star *R*, which would always be hid if the Earth never removed from *A*; and consequently, as the Earth turns round it's Axis, the point *N* would always come round to the Sun and Star at the same time. But when the Earth has advanced, suppose a twelfth part of it's Orbit from *A* to *B*, it's motion round it's Axis will bring the point *N* a twelfth part of a natural day, or two hours, sooner to the Star than to the Sun; for the Angle *NBn* is equal to the Angle *ASB*; and therefore any Star, which comes to the Meridian at noon with the Sun when the Earth is at *A*, will come to the Meridian at 10 in the forenoon when the Earth is at *B*. When the Earth comes to *C*, the point *N* will have the Star on it's Meridian at 8 in the morning, or four hours sooner than it comes round to the Sun; for it must revolve from *N* to *n*, before it has the Sun in it's Meridian. When the Earth comes to *D*, the point *N* will have the Star on it's Meridian at 6 in the morning, but that point must revolve six hours more from *N* to *n*, before it has mid-day by the Sun: for now the Angle *ASD* is a right Angle, and so is *NDn*; that is, the Earth has advanced 90 degrees in it's Orbit, and must turn 90 degrees on it's Axis to carry the point *N* from the Star to the Sun: for the Star always comes to the Meridian when *Nm* is parallel to *RSA*; because *DS* is but a point in respect of *RS*. When the Earth is at *E*, the Star comes to the Meridian at 4 in the morning; at *F*, at 2 in the morning; and at *G*, the Earth having gone half round it's Orbit, *N* points to the Star *R* at midnight, it being then directly opposite to the Sun; and therefore, by the Earth's diurnal motion, the Star comes to the Meridian 12 hours before the Sun. When the Earth is at *H*, the Star comes to the Meridian at 10 in the evening; at *I* it comes to the Meridian at 8, that is, 16 hours before the Sun; at *K* 18 hours before him; at *L* 20 hours; at *M* 22; and at *A* equally with the Sun again.

A TABLE, shewing how much of the Celestial Equator passes over the Meridian in any part of a mean SOLAR DAY; and how much the FIXED STARS gain upon the mean SOLAR TIME every Day, for a Month.

Time	Motion.			Time	Motion.			Time	Motion.			Acceleration of the Fixed Stars.			
Hours	Degrees	Minutes	Seconds	*Min. | Sec. | Th.	Deg. | Min. | Sec.	Min. | Sec. | Th.	Sec. | Th. | ''''	*Min | Sec. | Th.	Deg. | Min. | Sec	Min. | Sec. | Th	Sec. | Th. | ''''	D.	H.	M.	S.
1	15	2	28	1	0	15	2	31	7	46	16	1	0	3	56
2	30	4	56	2	0	30	5	32	8	1	19	2	0	7	52
3	45	7	24	3	0	45	7	33	8	16	2	3	0	11	48
4	60	9	51	4	1	0	10	34	8	31	24	4	0	15	44
5	75	12	19	5	1	15	12	35	8	46	26	5	0	19	39
6	90	14	47	6	1	30	15	36	9	1	29	6	0	23	35
7	105	17	15	7	1	45	17	37	9	16	31	7	0	27	31
8	120	19	43	8	2	0	20	38	9	31	34	8	0	31	27
9	135	22	11	9	2	15	22	39	9	46	36	9	0	35	23
10	150	24	38	10	2	30	25	40	10	1	39	10	0	39	19
11	165	27	6	11	2	45	27	41	10	16	41	11	0	43	15
12	180	29	34	12	3	0	30	42	10	31	43	12	0	47	11
13	195	32	2	13	3	15	32	43	10	46	46	13	0	51	7
14	210	34	30	14	3	30	34	4	11	1	48	14	0	55	3
15	225	36	58	15	3	45	37	45	11	16	51	15	0	58	58
16	240	39	26	16	4	0	39	46	11	31	53	16	1	2	54
17	255	41	53	17	4	15	41	47	11	46	56	17	1	6	50
18	270	44	21	18	4	30	44	48	12	1	58	18	1	10	46
19	285	46	49	19	4	45	47	49	12	17	1	19	1	14	47
20	300	49	17	20	5	0	49	50	12	32	3	20	1	18	38
21	315	51	45	21	5	15	52	51	12	47	6	21	1	22	34
22	330	54	13	22	5	30	54	52	13	2	8	22	1	26	30
23	345	56	40	23	5	45	57	53	13	17	11	23	1	30	26
24	360	59	8	24	6	0	59	54	13	32	13	24	1	34	22
25	376	1	36	25	6	16	2	55	13	47	16	25	1	38	17
26	391	4	4	26	6	31	4	56	14	2	18	26	1	42	13
27	406	6	32	27	6	46	7	57	14	17	21	27	1	46	9
28	421	9	0	28	7	1	9	58	14	32	23	28	1	50	5
29	436	11	28	29	7	16	11	59	14	47	26	29	1	54	1
30	451	13	56	30	7	31	14	60	15	2	28	30	1	57	57

PLATE III.

An absolute turn of the Earth on it's Axis never finishes a solar day.

222. Thus it is plain, that an absolute turn of the Earth on it's Axis (which is always completed when any particular Meridian comes to be parallel to it's situation at any time of the day before) never brings the same Meridian round from the Sun to the Sun again; but that the Earth requires as much more than one turn on it's Axis to finish a natural day, as it has gone forward in that time; which, at a mean state, is a 365th part of a Circle. Hence, in 365 days the Earth turns 366 times round it's Axis; and therefore, as a turn of the Earth on it's Axis completes a sydereal day, there must be one sydereal day more in a year than the number of solar days, be the number what it will, on the Earth, or any other Planet. One turn being lost with respect to the number of solar days in a year, by the Planet's going round the Sun; just as it would be lost to a traveller, who, in going round the Earth, would lose one day by following the apparent diurnal motion of the Sun; and consequently would reckon one day less at his return (let him take what time he would to go round the Earth) than those who remained all the while at the place from which he set out. So, if there were two Earths revolving equably on their Axes, and if one remained at *A* until the other had gone round the Sun from *A* to *A* again, *that* Earth which kept it's place at *A* would have it's solar and sydereal days always of the same length; and so would have one solar day more than the other at it's return. Hence, if the Earth turned but once round it's Axis in a year, and if *that* turn was made the same way as the Earth goes round the Sun, there would be continual day on one side of the Earth, and continual night on the other.

Fig. II.

223. The first part of the preceding Table shews how much of the celestial Equator passes over the Meridian in any given part of a mean solar day, and is to be understood the same way as the Table in the 220th article. The latter part, intitled,

Accele-

Accelerations of the fixed Stars, affords us an eaſy method of knowing whether or no our clocks and watches go true: For if, through a ſmall hole in a window-ſhutter, or in a thin plate of metal fixed to a window, we obſerve at what time any Star diſappears behind a chimney, or corner of a houſe, at a little diſtance; and if the ſame Star diſappears the next night 3 minutes 56 ſeconds ſooner by the clock or watch; and on the ſecond night, 7 minutes 52 ſeconds ſooner; the third night 11 minutes 48 ſeconds ſooner; and ſo on, every night, as in the Table, which ſhews this difference for 30 natural days, it is an infallible ſign that the machine goes true; otherwiſe it does not go true; and muſt be regulated accordingly: and as the diſappearing of a Star is inſtantaneous, we may depend on this information to half a ſecond. To know by the Stars whether a Clock goes true or not.

C H A P. XIII.

Of the Equation of Time.

224. THE Earth's motion on it's Axis being perfectly uniform, and equal at all times of the year, the ſydereal days are always preciſely of an equal length; and ſo would the ſolar or natural days be, if the Earth's Orbit were a perfect Circle, and it's Axis perpendicular to it's Orbit. But the Earth's diurnal motion on an inclined Axis, and it's annual motion in an elliptic Orbit, cauſe the Sun's apparent motion in the Heavens to be unequal: for ſometimes he revolves from the Meridian to the Meridian again in ſomewhat leſs than 24 hours, ſhewn by a well-regulated clock; and at other times in ſomewhat more: ſo that the time ſhewn by an equal going clock and a true Sun-dial is never the ſame but on the 15th of *April*, the 16th of *June*, the 31ſt of *Auguſt*, and the 24th of *December*. The clock, if it goes equally, and true all the year round, will be before the Sun The Sun and Clocks equal only on four days of the year.

from the 24th of *December* till the 15th of *April*; from that time till the 16th of *June* the Sun will be before the clock; from the 16th of *June* till the 31ſt of *Auguſt* the clock will be again before the Sun; and from thence to the 24th of *December* the Sun will be faſter than the clock.

Uſe of the Equation Table.

225. The Tables of the Equation of natural days, at the end of the following Chapter, ſhew the time that ought to be pointed out by a well-regulated clock or watch, every day of the year, at the preciſe moment of ſolar noon; that is, when the Sun's center is on the Meridian, or when a true Sun-dial ſhews it to be preciſely Twelve. Thus, on the 5th of *January* in Leap-year, when the Sun is on the Meridian, it ought to be 5 minutes 51 ſeconds paſt twelve by the clock: and on the 15th of *May*, when the Sun is on the Meridian, the time by the clock ſhould be but 55 minutes 57 ſeconds paſt eleven: in the former caſe, the clock is 5 minutes 51 ſeconds beforehand with the Sun; and in the latter caſe, the Sun is 4 minutes 3 ſeconds faſter than the clock. The column at the right hand of each month ſhews the daily difference of this equation, as it increaſes or decreaſes. But without a Meridian Line, or a Tranſit-Inſtrument fixed in the plane of the Meridian, we cannot ſet a Sun-dial true.

How to draw a Meridian Line.

226. The eaſieſt and moſt expeditious way of drawing a Meridian Line is this: Make four or five concentric Circles, about a quarter of an inch from one another, on a flat board about a foot in breadth; and let the outmoſt Circle be but little leſs than the board will contain. Fix a pin perpendicularly in the center, and of ſuch a length that it's whole ſhadow may fall within the innermoſt Circle for at leaſt four hours in the middle of the day. The pin ought to be about an eighth part of an inch thick, and to have a round blunt point. The board being ſet exactly level in a place where

where the Sun ſhines, ſuppoſe from eight in the morning till four in the afternoon, about which hours the end of the ſhadow ſhould fall without all the Circles; watch the times in the forenoon, when the extremity of the ſhortening ſhadow juſt touches the ſeveral Circles, and *there* make marks. Then, in the afternoon of the ſame day, watch the lengthening ſhadow, and where it's end touches the ſeveral Circles in going over them, make marks alſo. Laſtly, with a pair of compaſſes, find exactly the middle point between the two marks on any Circle, and draw a ſtraight line from the center to that point; which Line will be covered at noon by the ſhadow of a ſmall upright wire, which ſhould be put in the place of the pin. The reaſon for drawing ſeveral Circles is, that in caſe one part of the day ſhould prove clear, and the other part ſomewhat cloudy, if you miſs the time when the point of the ſhadow ſhould touch one Circle, you may perhaps catch it in touching another. The beſt time for drawing a Meridian Line in this manner is about the ſummer ſolſtice; becauſe the Sun changes his declination ſloweſt and his altitude faſteſt in the longeſt days.

If the caſement of a window on which the Sun ſhines at noon be quite upright, you may draw a line along the edge of it's ſhadow on the floor, when the ſhadow of the pin is exactly on the Meridian Line of the board: and as the motion of the ſhadow of the caſement will be much more ſenſible on the floor, than that of the ſhadow of the pin on the board, you may know to a few ſeconds when it touches the Meridian Line on the floor; and ſo regulate your clock for the day of obſervation by that line and the Equation Tables above-mentioned, § 225.

227. As the Equation of time, or difference between the time ſhewn by a well-regulated Clock and a true Sun-dial, depends upon two cauſes, Equation of natural days explained.

 namely,

namely, the obliquity of the Ecliptic, and the unequal motion of the Earth in it, we ſhall firſt explain the effects of theſe cauſes ſeparately conſidered, and then the united effects reſulting from their combination.

228. The Earth's motion on it's Axis being perfectly equable, or always at the ſame rate, and the * plane of the Equator being perpendicular to it's Axis, it is evident that in equal times equal portions of the Equator paſs over the Meridian; and ſo would equal portions of the Ecliptic, if it were parallel to or coincident with the Equator. But, as the Ecliptic is oblique to the Equator, the equable motion of the Earth carries unequal portions of the Ecliptic over the Meridian in equal times, the difference being proportionate to the obliquity; and as ſome parts of the Ecliptic are much more oblique than others, thoſe differences are unequal among themſelves. Therefore, if two Suns ſhould ſtart either from the beginning of Aries or Libra, and continue to move through equal arcs in equal times, one in the Equator, and the other in the Ecliptic, the equatoreal Sun would always return to the Meridian in 24 hours time, as meaſured by a well-regulated clock; but the Sun in the Ecliptic would return to the Meridian ſometimes ſooner, and ſometimes later than the equatoreal Sun; and only at the ſame moments with him on four days of the year; namely, the 20th of *March*, when the Sun enters Aries; the 21ſt of *June*, when he enters Cancer; the 23d of *September*, when he enters Libra; and the 21ſt of *December*, when he enters Capricorn. But, as there is only one Sun, and his apparent motion is always in the Ecliptic,

The firſt part of the Equation of time.

* If the Earth were cut along the Equator, quite through the center, the flat ſurface of this ſection would be the plane of the Equator; as the paper contained within any Circle may be juſtly termed the plane of that Circle.

let

let us henceforth call him the real Sun, and the other, which is ſuppoſed to move in the Equator, the fictitious; to which laſt, the motion of a well-regulated clock always anſwers. PLATE VI.

Let *Z*♈*z*♎ be the Earth, *ZFRz* it's Axis, *abcde* &c. the Equator, *ABCDE* &c. the northern half of the Ecliptic from ♈ to ♎ on the ſide of the Globe next the eye; and *MNOP* &c. the ſouthern half on the oppoſite ſide from ♎ to ♈. Let the points at *A*, *B*, *C*, *D*, *E*, *F*, &c. quite round from ♈ to ♈ again bound equal portions of the Ecliptic, gone through in equal times by the real Sun; and thoſe at *a*, *b*, *c*, *d*, *e*, *f*, &c. equal portions of the Equator deſcribed in equal times by the fictitious Sun; and let *Z*♈*z* be the Meridian. Fig. III.

As the real Sun moves obliquely in the Ecliptic, and the fictitious Sun directly in the Equator, with reſpect to the Meridian; a degree, or any number of degrees, between ♈ and *F* on the Ecliptic, muſt be nearer the Meridian *Z*♈*z*, than a degree, or any correſponding number of degrees on the Equator from ♈ to *f*; and the more ſo, as they are the more oblique: and therefore the true Sun comes ſooner to the Meridian every day whilſt he is in the quadrant ♈ *F*, than the fictitious Sun does in the quadrant ♈ *f*; for which reaſon, the ſolar noon precedes noon by the Clock, until the real Sun comes to *F*, and the fictitious to *f*; which two points, being equidiſtant from the Meridian, both Suns will come to it preciſely at noon by the Clock.

Whilſt the real Sun deſcribes the ſecond quadrant of the Ecliptic *FGHIKL* from ♋ to ♎, he comes later to the Meridian every day, than the fictitious Sun moving through the ſecond quadrant of the Equator from *f* to ♎; for the points at *G*, *H*, *I*, *K*, and *L* being farther from the Meridian than their correſponding points at *g*, *h*, *i*, *k*, and *l*, they muſt be later of coming to it: and as both

both Suns come at the ſame moment to the point ♎, they come to the Meridian at the moment of noon by the Clock.

In departing from Libra, through the third quadrant, the real Sun going through *MNOPQ* towards ♑ at *R*, and the fictitious Sun through *mnopq* towards *r*, the former comes to the Meridian every day ſooner than the latter, until the real Sun comes to ♑, and the fictitious to *r*, and then they both come to the Meridian at the ſame time.

Laſtly, as the real Sun moves equably through *STUVW*, from ♑ towards ♈; and the fictitious Sun through *stuvw*, from *r* towards ♈, the former comes later every day to the Meridian than the latter, until they both arrive at the point ♈, and then they make it noon at the ſame time with the clock.

A Table of the Equation of Time depending on the Sun's place in the Ecliptic.

229. The annexed Table ſhews how much the Sun is faſter or ſlower than the clock ought to be, ſo far as the difference depends upon the obliquity of the Ecliptic; of which the Signs of the firſt and third quadrants are at the head of the Table, and their Degrees at the left hand; and in theſe the Sun is faſter than the Clock: the Signs of the ſecond and fourth quadrants are at the foot of the Table, and their degrees at the right hand; in all which the Sun is ſlower than the Clock: ſo that entering the Table with the given Sign of the Sun's place at the head of the Table, and the Degree of his place in that Sign at the left hand; or with the given Sign at the foot of the Table, and Degree at the right hand; in the Angle of meeting is the number of minutes and ſeconds that the Sun is faſter or ſlower than the clock: or in other words, the quantity of time in which the real Sun, when in that part of the Ecliptic, comes ſooner or later to the meridian than the fictitious Sun in the Equator. Thus, when

when the Sun's place is ♉ Taurus 12 degrees, he is 9 minutes 49 seconds faster than the clock; and when his place is ♋ Cancer 18 degrees, he is 6 minutes 2 seconds slower.

Sun faster than the Clock in							
Degrees.	♈ ♎		♉ ♏		♊ ♐		1st Q. 3d Q.
	′	″	′	″	′	″	Deg.
0	0	0	8	24	8	46	30
1	0	20	8	35	8	36	29
2	0	40	8	45	8	25	28
3	1	0	8	54	8	14	27
4	1	19	9	3	8	1	26
5	1	39	9	11	7	49	25
6	1	59	9	18	7	35	24
7	2	18	9	24	7	21	23
8	2	37	9	31	7	6	22
9	2	56	9	36	6	51	21
10	3	16	9	41	6	35	20
11	3	34	9	45	6	19	19
12	3	53	9	49	6	2	18
13	4	11	9	51	5	45	17
14	4	29	9	53	5	27	16
15	4	47	9	54	5	9	15
16	5	4	9	55	4	50	14
17	5	21	9	55	4	31	13
18	5	38	9	54	4	12	12
19	5	54	9	52	3	52	11
20	6	10	9	50	3	32	10
21	6	26	9	47	3	12	9
22	6	41	9	43	2	51	8
23	6	55	9	38	2	30	7
24	7	9	9	33	2	9	6
25	7	23	9	27	1	48	5
26	7	36	9	20	1	27	4
27	7	49	9	13	1	5	3
28	8	1	9	5	0	43	2
29	8	13	8	56	0	22	1
30	8	24	8	46	0	0	0
2d Q. 4th Q.	♍ ♓		♌ ♒		♋ ♑		Deg.
Sun slower than the Clock in							

230. This

PLATE VI. Fig. III. 230. This part of the Equation of time may perhaps be ſomewhat difficult to underſtand by a Figure, becauſe both halves of the Ecliptic ſeem to be on the ſame ſide of the Globe; but it may be made very eaſy to any perſon who has a real Globe before him, by putting ſmall patches on every tenth or fifteenth degree both of the Equator and Ecliptic, beginning at Aries ♈; and then, turning the ball ſlowly round weſtward, he will ſee all the patches from Aries to Cancer come to the brazen Meridian ſooner than the correſponding patches on the Equator; all thoſe from Cancer to Libra will come later to the Meridian than their correſponding patches on the Equator; thoſe from Libra to Capricorn ſooner, and thoſe from Capricorn to Aries later: and the patches at the beginnings of Aries, Cancer, Libra, and Capricorn, being either on, or even with thoſe on the Equator, ſhew that the two Suns either meet there, or are even with one another, and ſo come to the Meridian at the ſame moment.

A machine for ſhewing the ſydereal, the equal, and the ſolar Time.

231. Let us ſuppoſe that there are two little balls moving equably round a celeſtial Globe by clock-work, one always keeping in the Ecliptic, and gilt with gold, to repreſent the real Sun; and the other keeping in the Equator, and ſilvered, to repreſent the fictitious Sun: and that whilſt theſe balls move once round the Globe according to the order of Signs, the Clock turns the Globe 366 times round it's Axis weſtward. The Stars will make 366 diurnal revolutions from the braſen Meridian to it again; and the two balls repreſenting the real and fictitious Sun always going farther eaſtward from any given Star, will come later than it to the Meridian every following day; and each ball will make 365 revolutions to the Meridian; coming equally to it at the beginnings of Aries, Cancer, Libra, and Capricorn: but in every other point of the Ecliptic, the gilt ball will come either ſooner or later to the Meridian than

than the ſilvered ball, like the patches above-mentioned. This would be a pretty enough way of ſhewing the reaſon why any given Star, which, on a certain day of the year, comes to the Meridian with the Sun, paſſes over it ſo much ſooner every following day, as on that day twelvemonth to come to the Meridian with the Sun again; and alſo to ſhew the reaſon why the real Sun comes to the Meridian ſometimes ſooner, ſometimes later, than it is noon by the clock; and, on four days of the year, at the ſame time; whilſt the fictitious Sun always comes to the Meridian when it is twelve at noon by the clock. This would be no difficult taſk for an artiſt to perform; for the gold ball might be carried round the Ecliptic by a wire from it's north Pole, and the ſilver ball round the Equator by a wire from it's ſouth Pole, by means of a few wheels to each; which might be eaſily added to my improvement of the celeſtial Globe, deſcribed in N° 483 of the *Philoſophical Tranſactions*; and of which I ſhall give a deſcription in the latter part of this Book, from the third Figure of the third plate. PLATE VI.

232. It is plain that if the Ecliptic were more obliquely poſited to the Equator, as the dotted Circle ♈ *x* ♎, the equal diviſions from ♈ to *x* would come ſtill ſooner to the Meridian Z o ♈ than thoſe marked *A*, *B*, *C*, *D*, and *E* do: for two diviſions containing 30 degrees, from ♈ to the ſecond dot, a little ſhort of the figure 1, come ſooner to the Meridian than one diviſion containing only 15 degrees from ♈ to *A* does, as the Ecliptic now ſtands; and thoſe of the ſecond quadrant from *x* to ♎ would be ſo much later. The third quadrant would be as the firſt, and the fourth as the ſecond. And it is likewiſe plain, that where the Ecliptic is moſt oblique, namely about Aries and Libra, the difference would be greateſt; and leaſt about Cancer and Capricorn, where the obliquity is leaſt. Fig. III.

234. Having

PLATE VI. The ſecond part of the Equation of Time.

234. Having explained one cauſe of the difference of time ſhewn by a well-regulated Clock and a true Sun-dial; and conſidered the Sun, not the Earth, as moving in the Ecliptic; we now proceed to explain the other cauſe of this difference, namely, the inequality of the Sun's apparent motion, § 205, which is ſloweſt in ſummer, when the Sun is fartheſt from the Earth, and ſwifteſt in winter when he is neareſt to it. But the Earth's motión on it's Axis is equable all the year round, and is performed from weſt to eaſt; which is the way that the Sun appears to change his place in the Ecliptic.

235. If the Sun's motion were equable in the Ecliptic, the whole difference between the equal time as ſhewn by a Clock, and the unequal time as ſhewn by the Sun, would ariſe from the obliquity of the Ecliptic. But the Sun's motion ſometimes exceeds a degree in 24 hours, though generally it is leſs: and when his motion is ſloweſt, any particular Meridian will revolve ſooner to him than when his motion is quickeſt; for it will overtake him in leſs time when he advances a leſs ſpace than when he moves through a larger.

236. Now, if there were two Suns moving in the plane of the Ecliptic, ſo as to go round it in a year; the one deſcribing an equal arc every 24 hours, and the other deſcribing ſometimes a leſs arc in 24 hours, and at other times a larger; gaining at one time of the year what it loſt at the oppoſite; it is evident that either of theſe Suns would come ſooner or later to the Meridian than the other, as it happened to be behind or before the other: and when they were both in conjunction, they would come to the Meridian at the ſame moment.

237. As the real Sun moves unequably in the Ecliptic, let us ſuppoſe a fictitious Sun to move equably in a circle coincident with the plane of the Ecliptic. Let *ALCD* be the Ecliptic or Orbit

Fig. IV.

in

in which the real Sun moves, and the dotted Circle *abcd* the imaginary Orbit of the fictitious Sun; each going round in a year according to the order of letters, or from west to east. Let *HIKL* be the Earth turning round it's Axis the same way every 24 hours; and suppose both Suns to start from *A* and *a*, in a right line with the plane of the Meridian *EH*, at the same moment: the real Sun at *A*, being then at his greatest distance from the Earth, at which time his motion is slowest; and the fictitious Sun at *a*, whose motion is always equable, because his distance from the Earth is supposed to be always the same. In the time that the Meridian revolves from *H* to *H* again, according to the order of the letters *HIKL*, the real Sun has moved from *A* to *F*; and the fictitious with a quicker motion from *a* to *f*, through a larger arc: therefore, the Meridian *EH* will revolve sooner from *H* to *h* under the real Sun at *F*, than from *H* to *k* under the fictitious Sun at *f*; and consequently it will then be noon by the Sun-dial sooner than by the Clock.

As the real Sun moves from *A* towards *C*, the swiftness of his motion increases all the way to *C*, where it is at the quickest. But notwithstanding this, the fictitious Sun gains so much upon the real, soon after his departing from *A*, that the increasing velocity of the real Sun does not bring him up with the equally moving fictitious Sun till the former comes to *C*, and the latter to *c*, when each has gone half round it's respective Orbit; and then being in conjunction, the Meridian *EH* revolving to *EK* comes to both Suns at the same time, and therefore it is noon by them both at the same moment.

But the increased velocity of the real Sun, now being at the quickest, carries him before the fictitious one; and therefore, the same Meridian will come to the fictitious Sun sooner than to the real: for whilst the fictitious Sun moves from *c* to *g*, the

PLATE VI. the real Sun moves through a greater arc from *C* to *G*: consequently the point *K* has it's noon by the Clock when it comes to *k*, but not it's noon by the Sun till it comes to *l*. And although the velocity of the real Sun diminishes all the way from *C* to *A*, and the fictitious Sun by an equable motion is still coming nearer to the real Sun, yet they are not in conjunction till the one comes to *A* and the other to *a*; and then it is noon by them both at the same moment.

Thus it appears, that the solar noon is always later than noon by the clock whilst the Sun goes from *C* to *A*, sooner whilst he goes from *A* to *C*, and at these two points the Sun and Clock being equal, it is noon by them both at the same moment.

Apogee, Perigee, and Apsides, what. 238. The point *A* is called *the Sun's Apogee*, because when he is there he is at his greatest distance from the Earth; the point *C* his *Perigee*, because when in it he is at his least distance from the Earth: and a right line, as *AEC*, drawn through the Earth's center, from one of these points to the other, is called *the line of the Apsides*. Fig. IV.

239. The distance that the Sun has gone in any time from his Apogee (not the distance he has to go to it, though ever so little) is called *his mean Anomaly*, and is reckoned in Signs and Degrees, allowing 30 Degrees to a Sign. Thus, when the Sun has gone suppose 174 degrees from his Apogee at *A*, he is said to be 5 Signs 24 Degrees from it, which is his mean Anomaly: and when he is gone suppose 355 degrees from his Apogee, he is said to be 11 Signs 25 Degrees from it, although he be but 5 Degrees short of *A* in coming round to it again. Mean Anomaly, what.

240. From what was said above, it appears, that when the Sun's Anomaly is less than 6 Signs, that is, when he is any where between *A* and *C*, in the half *ABC* of his Orbit, the solar noon pre-

cedes the clock noon; but when his Anomaly is more than 6 Signs, that is, when he is any where between *C* and *A*, in the half *CDA* of his Orbit, the clock noon precedes the ſolar. When his Anomaly is 0 Signs 0 Degrees, that is, when he is in his Apogee at *A*; or 6 Signs 0 Degrees, which is when he is in his Perigee at *C*; he comes to the Meridian at the moment that the fictitious Sun does, and then it is noon by them both at the ſame inſtant.

241. The following Table ſhews the Variation, or Equation of time depending on the Sun's Anomaly, and ariſing from his unequal motion in the Ecliptic; as the former Table, § 229, ſhews the Variation depending on the Sun's place, and reſulting from the obliquity of the Ecliptic: this is to be underſtood the ſame way as the other, namely, that when the Signs are at the head of the Table, the Degrees are at the left hand; but when the Signs are at the foot of the Table, the reſpective Degrees are at the right hand; and in both caſes the Equation is in the Angle of meeting. When both the above-mentioned Equations are either faſter or ſlower, their ſum is the abſolute Equation of Time; but when the one is faſter, and the other ſlower, it is their difference. Thus, ſuppoſe the Equation depending on the Sun's place, be 6 minutes 41 ſeconds too ſlow, and the Equation depending on the Sun's Anomaly, be 4 minutes 20 ſeconds too ſlow, their Sun is 11 minutes 1 ſecond too ſlow. But if the one had been 6 minutes 41 ſeconds too faſt, and the other 4 minutes 20 ſeconds too ſlow, their difference would have been 2 minutes 21 ſeconds too faſt, becauſe the greater quantity is too faſt.

A Table of the Equation of Time, depending on the Sun's Anomaly.

Sun faster than the Clock if his Anomaly be

D.	0 Signs ′	″	1 ′	″	2 ′	″	3 ′	″	4 ′	″	5 ′	″	
0	0	0	3	48	6	39	7	45	6	47	3	57	30
1	0	8	3	55	6	43	7	45	6	43	3	50	29
2	0	16	4	2	6	47	7	45	6	39	3	43	28
3	0	24	4	9	6	51	7	45	6	35	3	35	27
4	0	32	4	16	6	54	7	45	6	30	3	28	26
5	0	40	4	22	6	58	7	44	6	26	3	20	25
6	0	48	4	29	7	1	7	44	6	21	3	13	24
7	0	56	4	35	7	5	7	43	6	16	3	5	23
8	1	3	4	42	7	8	7	42	6	11	2	58	22
9	1	11	4	48	7	11	7	41	6	6	2	50	21
10	1	19	4	54	7	14	7	40	6	1	2	42	20
11	1	27	5	0	7	17	7	38	5	56	2	35	19
12	1	35	5	6	7	20	7	37	5	51	2	27	18
13	1	43	5	12	7	22	7	35	5	45	2	19	17
14	1	50	5	18	7	25	7	34	5	40	2	11	16
15	1	58	5	24	7	27	7	32	5	34	2	3	15
16	2	6	5	30	7	29	7	30	5	28	1	55	14
17	2	13	5	35	7	31	7	28	5	22	1	47	13
18	2	21	5	41	7	33	7	25	5	16	1	39	12
19	2	28	5	46	7	35	7	23	5	10	1	31	11
20	2	36	5	52	7	36	7	20	5	4	1	22	10
21	2	43	5	57	7	38	7	18	4	58	1	14	9
22	2	51	6	2	7	39	7	15	4	51	1	6	8
23	2	58	6	7	7	41	7	12	4	45	0	58	7
24	3	6	6	12	7	42	7	9	4	38	0	50	6
25	3	13	6	16	7	43	7	5	4	31	0	41	5
26	3	20	6	21	7	43	7	2	4	25	0	33	4
27	3	27	6	26	7	44	6	58	4	18	0	25	3
28	3	34	6	30	7	44	6	55	4	11	0	17	2
29	3	41	6	34	7	45	6	51	4	4	0	8	1
30	3	48	6	39	7	45	6	47	3	57	0	0	0
	11 Signs		10		9		8		7		6		D.

Sun slower than the Clock if his Anomaly be

242. The obliquity of the Ecliptic to the Equator, which is the first mentioned cause of the Equation of Time, would make the Sun and Clocks agree on four days of the year; which are, when the Sun enters Aries, Cancer, Libra, and Capricorn: but the other cause, now explained, would

would make the Sun and Clocks equal only twice in a year; that is, when the Sun is in his Apogee and Perigee. Confequently, when thefe two points fall in the beginnings of Cancer and Capricorn, or of Aries and Libra, they concur in making the Sun and Clocks equal in thefe points. But the Apogee at prefent is in the 9th degree of Cancer, and the Perigee in the 9th degree of Capricorn; and therefore the Sun and Clocks cannot be equal about the beginnings of thefe Signs, nor at any time of the year, except when the fwiftnefs or flownefs of Equation refulting from one caufe juft balances the flownefs or fwiftnefs arifing from the other.

243. The fecond Table in the following Chapter fhews the Sun's place in the Ecliptic at the noon of every day by the Clock, for the fecond year after Leap-year; and alfo the Sun's Anomaly to the neareft degree, neglecting the odd minutes of that degree. It's ufe is only to affift in the method of making a general Equation Table from the two fore-mentioned Tables of Equation depending on the Sun's Place and Anomaly, § 229, 241; concerning which method we fhall give a few examples prefently. The next following Tables are made from thofe two; and fhew the abfolute Equation of Time refulting from the combination of both it's caufes; in which the minutes, as well as degrees, both of the Sun's Place and Anomaly are confidered. The ufe of thefe Tables is already explained, § 225; and they ferve for every day in Leap-year, and the firft, fecond, and third years after: For on moft of the fame days of all thefe years the Equation differs, becaufe of the odd fix hours more than the 365 days of which the year confifts.

Examples for making Equation Tables.

Example I. On the 15th of *April*, the Sun is in the 25th degree of ♈ Aries, and his Anomaly is 9 Signs 15 Degrees; the Equation refulting from the former is 7 minutes 23 ſeconds of time too faſt, § 229; and from the latter, 7 minutes 27 ſeconds too ſlow, § 241; the difference is 4 ſeconds that the Sun is too ſlow at the noon of that day; taking it in groſs for the degrees of the Sun's Place and Anomaly, without making proportionable allowance for the odd minutes. Hence, at noon the ſwiftneſs of the one Equation balancing ſo nearly the ſlowneſs of the other, makes the Sun and Clocks equal on ſome part of that day.

Example II. On the 16th of *June*, the Sun is in the 25th degree of ♊ Gemini, and his Anomaly is 11 Signs 16 Degrees; the Equation ariſing from the former is 1 minute 48 ſeconds too faſt; and from the latter 1 minute 50 ſeconds too ſlow; which balancing one another at noon to 2 ſeconds, the Sun and Clocks are again equal on that day.

Example III. On the 31ſt of *Auguſt*, the Sun's place is 7 degrees 52 minutes of ♍ Virgo (which we call the 8th degree, as it is ſo near) and his Anomaly is 2 Signs 0 Degrees; the Equation ariſing from the former is 6 minutes 41 ſeconds too ſlow; and from the latter 6 minutes 39 ſeconds too faſt; the difference being only 2 ſeconds too ſlow at noon, and decreaſing towards an equality, will make the Sun and Clocks equal in the afternoon of that day.

Example IV. On the 23d of *December*, the Sun's place is 1 degree 41 minutes (call it 2 degrees) of ♑ Capricorn, and his Anomaly is 5 Signs 23 Degrees; the Equation for the former is 43 ſeconds too ſlow, and for the latter 58 ſeconds too faſt; the difference is 15 ſeconds too faſt at noon; which decreaſing will come to an equality, and ſo make the Sun and Clocks equal in the evening of that day.

And thus we find, that on some part of each of the above-mentioned four days, the Sun and Clocks are equal; but if we work examples for all other days of the year, we shall find them different. And,

244. On those days which are equidistant from any Equinox or Solstice, we do not find that the Equation is as much too fast or too slow, on the one side, as it is too slow or too fast on the other. The reason is, that the line of the Apsides, § 238, does not, at present, fall either into the Equinoctial or Solstitial points, § 242. Remark.

The four following Equation Tables, for Leap-year, and the first, second, and third years after, would serve for ever, if the Sun's Place and Anomaly were always the same on every given day of the year as on the same day four years before or after. But since that is not the case, no general Equation Tables can be so constructed as to be perpetual. The reason why Equation Tables are but temporary.

CHAP. XIV.

Of the Precession of the Equinoxes.

246. IT has been already observed, § 116, that by the Earth's motion on it's Axis, there is more matter accumulated all around the equatoreal parts than any where else on the Earth.

The Sun and Moon, by attracting this redundancy of matter, bring the Equator sooner under them in every return towards it, than if there was no such accumulation. Therefore, if the Sun sets out, as from any Star, or other fixed point in the Heavens, the moment when he is departing from the Equinoctial or from either Tropic, he will come to the same Equinox or Tropic again 20 min. $17\frac{1}{2}$ sec. of time, or 50 seconds of a degree, before he compleats his course so, as to arrive at the same fixed Star or Point from whence he set out. For,

PLATE VI. the Equinoctial points recede 50 ſeconds of a degree weſtward every year, contrary to the Sun's annual progreſſive motion.

When the Sun arrives at the ſame * Equinoctial or Solſtitial point, he finiſhes what we call the *Tropical Year*; which, by obſervation, is found to contain 365 days 5 hours 48 minutes 57 ſeconds: and when he arrives at the ſame fixed Star again, as ſeen from the Earth, he compleats the *Sydereal Year*, which contains 365 days 6 hours 9 minutes $14\frac{1}{2}$ ſeconds. The *Sydereal Year* is therefore 20 minutes $17\frac{1}{2}$ ſeconds longer than the Solar or Tropical year, and 9 minutes $14\frac{1}{2}$ ſeconds longer than the Julian or Civil year, which we ſtate at 365 days 6 hours: ſo that the Civil year is almoſt a mean betwixt the Sydereal and Tropical.

247. As the Sun deſcribes the whole Ecliptic, or 360 degrees, in a Tropical year, he moves $59' \, 8''$ of a degree every day at a mean rate; and conſequently $50''$ of a degree in 20 minutes $17\frac{1}{2}$ ſeconds of time: therefore, he will arrive at the ſame Equinox or Solſtice when he is $50''$ of a degree ſhort of the ſame Star or fixed point in the Heavens from which he ſet out in the year before. So that with reſpect to the fixed Stars, the Sun and Equinoctial points fall back (as it were) 30 degrees in 2160 years; which will make the Stars appear to have gone 30 deg. forward, with reſpect to the Signs of the Ecliptic in that time: for the ſame Signs always keep in the ſame points of the Ecliptic, without regard to the Conſtellations.

Fig. IV. To explain this by a Figure, let the Sun be in Conjunction with a fixed Star at *S*, ſuppoſe in the 30th degree of ♉, on the 21ſt day of *May* 1756. Then making 2160 revolutions through the Eclip-

* The two oppoſite points in which the Ecliptic croſſes the Equinoctial, are called *the Equinoctial points*: and the two points where the Ecliptic touches the Tropics (which are likewiſe oppoſite, and 90 degrees from the former) are called *the Solſtitial points*.

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tic *VWX*, at the end of ſo many Sydereal years, he will be found again at *S*: but at the end of ſo many Julian years, he will be found at *M*, ſhort of *S*: and at the end of ſo many Tropical years, he will be found ſhort of *M*, in the 30th deg. of Taurus at *T*, which has receded back from *S* to *T* in that time, by the Preceſſion of the Equinoctial points ♈ *Aries* and ♎ *Libra*. The Arc *ST* will be equal to the amount of the Preceſſion of the Equinox in 2160 years, at the rate of 50″ of a degree, or 20 min. 17½ ſec. of time, annually: this, in ſo many years, makes 30 days 10½ hours; which is the difference between 2160 Sydereal and Tropical years: And the Arc *MT* will be equal to the ſpace moved through by the Sun in 2160 times 11 min. 3 ſec. or 16 days 13 hours 48 minutes, which is the difference between 2160 Julian and Tropical years.

248. From the ſhifting of the Equinoctial points, and with them, all the Signs of the Ecliptic, it follows that thoſe Stars which in the infancy of Aſtronomy were in *Aries* are now got into *Taurus*; thoſe of *Taurus* into *Gemini*, &c. Hence likewiſe it is, that the Stars which roſe or ſet at any particular ſeaſon of the year, in the times of Hesiod, Eudoxus, Virgil, Pliny, &c. by no means anſwer at this time to their deſcriptions. The preceding Table ſhews the quantity of this ſhifting both in the Heavens and on the Earth, for any number of years to 25,920; which compleats the grand celeſtial period: within which any number and it's quantity is eaſily found; as in the following example, for 5763 years; which at the Autumnal Equinox, *A. D.* 1756, is thought to be the age of the world. So that with regard to the fixed Stars, the Equinoctial points in the Heavens, have receded 2ˢ 20° 2′ 30″ ſince the creation; which is as much as the Sun moves in 81ᵈ 5ʰ 0ᵐ 52ˢ. And ſince that time, or in 5763 years, the Equinoxes with us

us have fallen back $44^d\ 5^h\ 21^m\ 9^s$; hence, reckoning from the time of the *Julian* Equinox, *A. D.* 1756, *viz. Sept.* 11th, it appears that the Autumnal Equinox at the creation was on the 25th of *October*.

Julian years.	Preceſſion of the Equinoctial Points in the Heavens.								Anticipation of the Equinoxes on the Earth.			
	Motion.				Time.							
	s	°	′	″	D.	H.	M.	S.	D.	H.	M.	S.
5000	2	9	26	40	70	10	58	20	38	8	50	0
700	0	9	43	20	9	20	44	10	5	8	55	0
60	0	0	50	0	0	20	17	30	0	11	3	0
3	0	0	2	30	0	1	0	52	0	0	33	9
5763	2	20	2	30	81	5	0	52	44	5	21	9

249. The anticipation of the Equinoxes, and conſequently of the Seaſons, is by no means owing to the Preceſſion of the Equinoctial and Solſtitial points in the Heavens (which can only affect the apparent motions, places and declinations of the fixed Stars) but to the difference between the Civil and ſolar year, which is 11 minutes 3 ſeconds; the Civil year containing 365 days 6 hours, and the Solar year 365 days 5 hours 48 minutes 57 ſeconds. The following Table ſhews the length, and conſequently the difference of any number of Sydereal, Civil, and Solar years from 1 to 10,000. The anticipation of the Equinoxes and Seaſons.

250. The above 11 minutes 3 ſeconds, by which the Civil or Julian year exceeds the Solar, amounts to 11 days in 1433 years: and ſo much our ſeaſons have fallen back with reſpect to the days of the months, ſince the time of the *Nicene* Council in *A. D.* 325, and therefore in order to bring back all the Faſts and Feſtivals to the days then ſettled, The reaſon for altering the Style.

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PLATE VI. it was requiſite to ſuppreſs 11 nominal days. And that the ſame ſeaſons might be kept to the ſame times of the year for the future, to leave out the Biſſextile-day in *February* at the end of every century of years not diviſible by 4; reckoning them only common years, as the 17th, 18th, and 19th centuries, *viz.* the years 1700, 1800, 1900, *&c.* becauſe a day intercalated every fourth year was too much, and retaining the Biſſextile-day at the end of thoſe Centuries of years which are diviſible by 4, as the 16th, 20th, and 24th Centuries; *viz.* the years 1600, 2000, 2400, *&c.* Otherwiſe, in length of time the ſeaſons would be quite reverſed with regard to the months of the year; though it would have required near 23,783 years to have brought about ſuch a total change. If the Earth had made exactly $365\frac{1}{4}$ diurnal rotations on it's Axis, whilſt it revolved from any Equinoctial or Solſtitial point to the ſame again, the Civil and ſolar years would always have kept pace together; and the Style would never have needed any alteration.

The Preceſſion of the Equinoctial points. 251. Having already mentioned the cauſe of the Preceſſion of the Equinoctial points in the Heavens, § 246, which occaſions a ſlow deviation of the Earth's axis from it's paralleliſm, and thereby a change of the declination of the Stars from the Equator, together with a ſlow apparent motion of the Stars forward with reſpect to the Signs of the Ecliptic; we ſhall now deſcribe the Phenomena by a Diagram.

Fig. VI. Let *NZSVL* be the Earth, *SONA* it's Axis produced to the ſtarry Heavens, and terminating in *A*, the preſent north Pole of the Heavens, which is vertical to *N* the north Pole of the Earth. Let *EOQ* be the Equator, *T* ♋ *Z* the Tropic of Cancer, and *VT* ♑ the Tropic of Capricorn: *VOZ* the Ecliptic, and *BO* it's Axis, both which are immove-
able

able among the Stars. But, as * the Equinoctial points recede in the Ecliptic, the Earth's Axis *SON* is in motion upon the Earth's center *O*, in in ſuch a manner, as to deſcribe the double Cone *NOn* and *SOs*, round the Axis of the Ecliptic *BO*, in the time that the Equinoctial points move quite round the Ecliptic, which is 25,920 years; and in that length of time, the north Pole of the Earth's Axis produced, deſcribes the Circle *ABCDA* in the ſtarry Heavens, round the Pole of the Ecliptic, which keeps immoveable in the center of that Circle. The Earth's Axis being 23½ degrees inclined to the Axis of the Ecliptic, the Circle *ABCDA* deſcribed by the north Pole of the Earth's Axis produced in *A*, is 47 degrees in diameter, or double the inclination of the Earth's Axis. In conſequence of this, the point *A*, which at preſent is the north Pole of the Heavens, and near to a Star of the ſecond magnitude in the tail of the conſtellation called *the Little Bear*, muſt be deſerted by the Earth's Axis; which moving backwards a degree every 72 years, will be directed towards the Star or Point *B* in 6480 years hence: and in double of that time, or 12,960 years, it will be directed towards the Star or Point *C*; which will then be the north Pole of the Heavens, although it is at preſent 8½ degrees ſouth of the Zenith of *London L*. The preſent poſition of the Equator *EOQ*, will then be changed into *eOq*, the Tropic of Cancer *T*♋*Z* into *Vt*♋, and the Tropic of Capricorn *VT*♑ into *t*♑*Z*; as is evident by the Figure. And the Sun, in the ſame part of the Heavens where he is now over the

* The Equinoctial Circle interſects the Ecliptic in two oppoſite points, called *Aries* and *Libra*, from the Signs which always keep in theſe points: They are called the Equinoctial Points, becauſe when the Sun is in either of them, he is directly over the terreſtrial Equator; and then the days and nights are equal.

earthly Tropic of Capricorn, and makes the ſhorteſt days and longeſt nights in the Northern Hemiſphere, will then be over the earthly Tropic of Cancer, and make the days longeſt, and nights ſhorteſt. So that it will require 12,960 years yet more, or 25,920 from the then preſent time, to bring the north Pole *N* quite round, ſo as to be directed toward that point of the Heavens which is vertical to it at preſent. And then, and not till then, the ſame Stars which at preſent deſcribe the Equator, Tropics, and polar Circles, *&c.* by the Earth's diurnal motion, will deſcribe them over again.

TABLE *shewing the Time contained in any number of Sydereal, Julian, and Solar Years, from* 1 *to* 10000.

	Sydereal Years.				Julian Years.		Solar Years.			
Years	Days	H.	M.	S.	Days	H.	Days	H.	M.	S.
1	365	6	9	14	365	6	365	5	48	57
2	730	12	18	29	730	12	730	11	37	54
3	1095	18	27	43	1095	18	1095	17	26	51
4	1461	0	36	58	1461	0	1460	23	15	48
5	1826	6	46	12½	1826	6	1826	5	4	45
6	2191	12	55	27	2191	12	2191	10	53	42
7	2556	19	5	41½	2556	18	2556	16	42	39
8	2922	1	13	56	2922	0	2921	22	31	36
9	3287	7	23	10½	3287	6	3287	4	20	33
10	3652	13	32	25	3652	12	3652	10	9	30
20	7305	3	4	50	7305	0	7304	20	19	0
30	10957	16	37	15	10957	12	10957	6	28	30
40	14610	6	9	40	14610	0	14609	16	38	0
50	18262	19	42	5	18262	12	18262	2	47	30
60	21915	9	14	30	21915	0	21914	12	57	0
70	25567	22	46	55	25567	12	25565	23	6	30
80	29220	12	19	20	29220	0	29219	9	16	0
90	32873	1	51	45	32872	12	32871	19	25	30
100	36525	15	24	10	36525		36524	5	35	
200	73051	6	48	20	73050		73048	11	10	
300	109576	22	12	30	109575		109572	16	45	
400	146102	13	36	40	146100		146096	22	20	
500	182628	5	0	50	182625		182621	3	55	
600	219153	20	25		219150		219145	9	30	
700	255679	11	49	10	255675		255669	15	5	
800	292205	3	13	20	292200		292193	20	40	
900	328730	18	37	30	328725		328718	2	15	
1000	365256	10	1	40	365250		365242	7	50	
2000	730512	20	3	20	730500		730484	15	40	
3000	1095769	6	5		1095750		109572[illegible]	23	30	
4000	1461025	16	6	40	1461000		1460969	7	20	
5000	1826282	2	8	20	1826250		1826211	15	10	
6000	2191538	12	10		2191500		2191453	23	0	
7000	2556794	22	11	40	2556750		2556696	6	50	
8000	2922051	8	13	20	2922000		2921938	14	40	
9000	3287037	18	15		3287250		3287180	22	30	
10000	3652564	4	16	40	3652500		3652423	6	20	

A TABLE shewing the Sun's true Place, and Distance from his Apogee, for the second Year after Leap-year.

Days	January				February				March				April			
	Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.	
	D.	M.	S.	D.	D.	M.	S.	D.	D.	M	S.	D.	D.	M.	S.	D.
1	11 ♑	7	6	2	12 ♒	39	7	3	10 ♓	53	8	0	11 ♈	40	9	1
2	12	8	6	3	13	40	7	4	11	53	8	1	12	39	9	2
3	13	9	6	4	14	41	7	5	12	53	8	2	13	38	9	3
4	14	10	6	5	15	42	7	6	13	53	8	3	14	37	9	4
5	15	11	6	6	16	43	7	7	14	53	8	4	15	36	9	5
6	16	12	6	7	17	43	7	8	15	53	8	5	16	35	9	6
7	17	14	6	8	18	44	7	9	16	53	8	6	17	34	9	7
8	18	15	6	9	19	45	7	10	17	53	8	7	18	33	9	8
9	19	16	6	10	20	46	7	11	18	53	8	8	19	32	9	9
10	20	17	6	11	21	46	7	12	19	53	8	9	20	30	9	10
11	21	18	6	12	22	47	7	13	20	52	8	10	21	29	9	11
12	22	19	6	13	23	47	7	14	21	52	8	11	22	28	9	12
13	23	21	6	14	24	48	7	15	22	52	8	12	23	26	9	13
14	24	22	6	15	25	48	7	16	23	52	8	13	24	25	9	14
15	25	23	6	16	26	49	7	17	24	51	8	14	25	24	9	15
16	26	24	6	17	27	49	7	18	25	51	8	15	26	22	9	16
17	27	25	6	18	28	50	7	19	26	51	8	16	27	21	9	17
18	28	26	6	19	29	50	7	20	27	50	8	17	28	19	9	18
19	29	27	6	20	♓	51	7	21	28	50	8	18	29	18	9	19
20	♒	28	6	21	1	51	7	22	29	49	8	19	♉	16	9	20
21	1	29	6	22	2	51	7	23	♈	49	8	20	1	15	9	21
22	2	30	6	23	3	52	7	24	1	48	8	21	2	13	9	22
23	3	31	6	24	4	52	7	25	2	47	8	22	3	11	9	23
24	4	32	6	25	5	52	7	26	3	47	8	23	4	10	9	24
25	5	33	6	26	6	52	7	27	4	46	8	24	5	8	9	25
26	6	34	6	27	7	53	7	28	5	45	8	25	6	6	9	26
27	7	35	6	28	8	53	7	29	6	45	8	26	7	4	9	27
28	8	36	6	29	9	53	8	0	7	44	8	27	8	3	9	28
29	9	37	7	0					8	43	8	28	9	1	9	29
30	10	38	7	1					9	42	8	29	9	59	9	29
31	11	39	7	2					10	41	9	0				

A TABLE

A TABLE shewing the Sun's true Place, and Distance from his Apogee, for the second Year after Leap-year.

Days	May				June				July				August			
	Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom		Sun's Place.		Sun's Anom.		Sun's Place.		Sun's Anom.	
	D.	M.	S.	D.	D.	M.	S	D.	D.	M.	S.	D.	D.	M.	S.	D.
1	10 ♉	57	10	0	10 ♊	46	11	1	9 ♋	24	0	0	8 ♌	59	1	0
2	11	55	10	1	11	44	11	2	10	21	0	1	9	57	1	1
3	12	53	10	2	12	41	11	3	11	18	0	2	10	54	1	2
4	13	51	10	3	13	38	11	4	12	15	0	3	11	52	1	3
5	14	49	10	4	14	35	11	5	13	13	0	4	12	49	1	4
6	15	47	10	5	15	33	11	6	14	10	0	5	13	47	1	5
7	16	45	10	6	16	30	11	7	15	7	0	6	14	44	1	6
8	17	43	10	7	17	28	11	8	16	4	0	7	15	42	1	7
9	18	41	10	8	18	25	11	9	17	1	0	8	16	39	1	8
10	19	39	10	9	19	22	11	10	17	59	0	8	17	37	1	9
11	20	37	10	10	20	20	11	11	18	56	0	9	18	35	1	10
12	21	34	10	11	21	17	11	12	19	53	0	10	19	32	1	11
13	22	32	10	12	22	14	11	13	20	50	0	11	20	30	1	12
14	23	30	10	13	23	11	11	14	21	47	0	12	21	28	1	13
15	24	28	10	14	24	8	11	15	22	45	0	13	22	25	1	14
16	25	26	10	15	25	6	11	16	23	42	0	14	23	23	1	15
17	26	23	10	16	26	3	11	17	24	39	0	15	24	21	1	16
18	27	21	10	17	27	0	11	18	25	36	0	16	25	19	1	17
19	28	19	10	18	27	58	11	18	26	34	0	17	26	17	1	18
20	29	16	10	19	28	55	11	19	27	31	0	18	27	14	1	19
21	♊	15	10	20	29	52	11	20	28	28	0	19	28	12	1	20
22	1	11	10	21	♋	49	11	21	29	26	0	20	29	10	1	21
23	2	9	10	22	1	46	11	22	♌	23	0	21	♍	8	1	22
24	3	6	10	23	2	44	11	23	1	20	0	22	1	6	1	23
25	4	4	10	24	3	41	11	24	2	18	0	23	2	4	1	24
26	5	2	10	25	4	38	11	25	3	15	0	24	3	2	1	25
27	5	59	10	26	5	35	11	26	4	12	0	25	4	0	1	26
28	6	56	10	27	6	32	11	27	5	10	0	26	4	58	1	27
29	7	54	10	28	7	30	11	28	6	7	0	27	5	56	1	28
30	8	51	10	29	8	27	11	29	7	5	0	28	6	54	1	29
31	9	48	11	0					8	2	0	29	7	52	2	0

A TABLE

A TABLE ſhewing the Sun's true Place, and Diſtance from his Apogee, for the ſecond Year after Leap-year.

Days	September Sun's Place. D.	M.	Sun's Anom. S.	D.	October Sun's Place. D.	M.	Sun's Anom. S.	D.	November Sun's Place. D.	M.	Sun's Anom. S.	D.	December Sun's Place. D.	M.	Sun's Anom. S.	D.
1	8 ♍	51	2	1	8 ♎	10	3	1	9 ♏	0	4	2	9 ♐	18	5	1
2	9	49	2	2	9	9	3	2	10	0	4	3	10	19	5	2
3	10	47	2	3	10	8	3	3	11	0	4	4	11	20	5	3
4	11	45	2	4	11	8	3	4	12	1	4	5	12	21	5	4
5	12	43	2	5	12	7	3	5	13	1	4	6	13	22	5	5
6	13	42	2	6	13	6	3	6	14	1	4	7	14	23	5	6
7	14	40	2	7	14	6	3	7	15	2	4	8	15	24	5	7
8	15	39	2	8	15	5	3	8	16	2	4	9	16	25	5	8
9	16	37	2	9	16	4	3	9	17	2	4	10	17	26	5	9
10	17	35	2	10	17	4	3	10	18	3	4	11	18	27	5	10
11	18	34	2	11	18	3	3	11	19	3	4	12	19	28	5	11
12	19	32	2	12	19	3	3	12	20	4	4	13	20	29	5	12
13	20	31	2	13	20	2	3	13	21	4	4	14	21	30	5	13
14	21	29	2	14	21	2	3	14	22	5	4	15	22	31	5	14
15	22	28	2	15	22	2	3	15	23	5	4	16	23	32	5	15
16	23	27	2	16	23	1	3	16	24	6	4	17	24	33	5	16
17	24	25	2	17	24	1	3	17	25	7	4	18	25	34	5	17
18	25	24	2	18	25	1	3	18	26	7	4	19	26	35	5	18
19	26	23	2	19	26	0	3	19	27	8	4	20	27	36	5	19
20	27	21	2	20	27	0	3	20	28	9	4	21	28	38	5	20
21	28	20	2	21	28	0	3	21	29	9	4	22	29	39	5	21
22	29	19	2	22	29	0	3	22	♐	10	4	23	♑	40	5	22
23	♎	18	2	23	♏	0	3	23	1	11	4	24	1	41	5	23
24	1	17	2	24	1	0	3	24	2	12	4	25	2	42	5	24
25	2	16	2	25	2	0	3	25	3	12	4	26	3	44	5	25
26	3	15	2	26	3	0	3	26	4	13	4	27	4	45	5	26
27	4	14	2	27	4	0	3	27	5	14	4	28	5	46	5	27
28	5	13	2	28	5	0	3	28	6	15	4	29	6	47	5	28
29	6	12	2	29	6	0	3	29	7	16	4	29	7	48	5	29
30	7	11	3	0	7	0	4	0	8	17	5	0	8	49	6	0
31					8	0	4	1					9	51	6	1

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The Biſſextile, or Leap-year.

Days	January			Dif.	February			Dif.	March			Dif.	April			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Inc.				Inc.				Dec.				Dec.
1	12	4	0	28	12	14	5	7	12	12	36	13	12	3	48	18
2	12	4	28	28	12	14	12	7	12	12	23	13	12	3	30	19
3	12	4	56	28	12	14	19	6	12	12	10	14	12	3	11	18
4	12	5	24	27	12	14	25	5	12	11	56	14	12	2	53	18
5	12	5	51		12	14	30		12	11	42		12	2	35	
				27				4				14				18
6	12	6	18	26	12	14	34	3	12	11	28	15	12	2	17	17
7	12	6	44	26	12	14	37	3	12	11	13	15	12	2	0	17
8	12	7	10	25	12	14	40	2	12	10	58	16	12	1	43	17
9	12	7	35	25	12	14	42	1	12	10	42	16	12	1	26	17
10	12	8	0		12	14	43		12	10	4[illegible]		12	1	9	
				24				Dec.				16				16
11	12	8	24	23	12	14	44	1	12	10	10	17	12	0	53	16
12	12	8	47	23	12	14	43	1	12	9	5[illegible]	17	12	0	37	16
13	12	9	10	22	12	14	42	2	12	9	3[illegible]	17	12	0	21	15
14	12	9	32	22	12	14	40	3	12	9	19	17	12	0	6	15
15	12	9	54		12	14	37		12	9	2		11	59	51	
				21				4				18				15
16	12	10	15	20	12	14	33	4	12	8	44	18	11	59	3[illegible]	15
17	12	10	35	19	12	14	29	5	12	8	26	18	11	59	21	14
18	12	10	54	19	12	14	24	5	12	8	8	18	11	59	7	13
19	12	11	13	18	12	14	19	6	12	7	50	18	11	58	54	13
20	2	11	31		12	14	13		12	7	32		11	58	41	
				17				7				18				13
21	12	11	48	17	12	14	6	8	12	7	14	19	11	58	28	12
22	12	12	5	16	12	13	58	8	12	6	55	19	11	58	1[illegible]	12
23	12	12	21	15	12	13	50	9	12	6	36	19	11	58	4	12
24	12	12	36	14	12	13	41	9	12	6	17	19	11	57	52	1
25	12	12	50		12	13	32		12	5	58		11	57	4	
				13				10				18				10
26	12	13	3	12	12	13	22	11	12	5	40	19	11	57	31	10
27	12	13	15	12	12	13	11	11	12	5	21	19	11	57	21	9
28	12	13	27	11	12	13	0	12	12	5	2	18	11	57	12	9
29	12	13	38	10	12	12	48	12	12	4	44	19	11	57	5	8
30	12	13	48						12	4	25		11	56	55	
				9								19				8
31	12	13	57	8					12	4	6	18				

Incr. 9′ 57″ — Incr. 0′ 39″, Decr. 1 56 — Decr. 8′ 30″ — Decr. 6′ 53″

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The Bissextile, or Leap-year.

Days	May			Dif.	June			Dif.	July			Dif.	August			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Inc.				Inc.				Dec.
1	11	56	47	7	11	57	22	9	12	3	18	11	12	5	46	4
2	11	56	40	7	11	57	31	9	12	3	29	11	12	5	42	5
3	11	56	33	6	11	57	40	10	12	3	40	11	12	5	37	5
4	11	56	27	6	11	57	50	10	12	3	51	11	12	5	32	6
5	11	56	21		11	58	0		12	4	2		12	5	26	
				5				11				10				6
6	11	56	16	4	11	58	11	11	12	4	12	10	12	5	20	7
7	11	56	12	4	11	58	22	11	12	4	22	9	12	5	13	8
8	11	56	8	4	11	58	33	11	12	4	31	9	12	5	5	8
9	11	56	4	3	11	58	44	12	12	4	40	8	12	4	57	9
10	11	56	1		11	58	56		12	4	48		12	4	48	
				2				12				8				9
11	11	55	59	1	11	59	8	12	12	4	56	8	12	4	39	10
12	11	55	58	1	11	59	20	12	12	5	4	7	12	4	29	10
13	11	55	57	Inc.	11	59	32	12	12	5	11	7	12	4	19	11
14	11	55	56	1	11	59	44	13	12	5	18	6	12	4	8	12
15	11	55	57		11	59	57		12	5	24		12	3	56	
				1				13				6				12
16	11	55	58	1	12	0	10	13	12	5	30	5	12	3	44	12
17	11	55	59	2	12	0	23	12	12	5	35	5	12	3	32	13
18	11	56	1	2	12	0	35	13	12	5	40	4	12	3	19	13
19	11	56	3	3	12	0	48	13	12	5	44	4	12	3	6	14
20	11	56	6		12	1	1		12	5	48		12	2	52	
				3				13				3				14
21	11	56	9	4	12	1	14	13	12	5	51	2	12	2	38	15
22	11	56	13	5	12	1	27	13	12	5	53	2	12	2	23	15
23	11	56	18	5	12	1	40	13	12	5	55	2	12	2	8	16
24	11	56	23	6	12	1	53	13	12	5	57	1	12	1	52	16
25	11	56	29		12	2	6		12	5	58		12	1	36	
				6				12				1				17
26	11	56	35	7	12	2	18	13	12	5	59	Dec.	12	1	19	17
27	11	56	42	7	12	2	31	12	12	5	58	1	12	1	2	17
28	11	56	49	7	12	2	43	12	12	5	57	2	12	0	45	17
29	11	56	56	8	12	2	55	12	12	5	55	2	12	0	28	18
30	11	57	4		12	3	7		12	5	53		12	0	10	
				9				11				3				18
31	11	57	13	9					12	5	50	4	11	59	52	19

Decr. 0′ 50″ Incr. 1 17 | Incr. 5′ 45″ | Incr. 2′ 41″ Decr. 0 8 | Decr. 5′ 54″

A TABLE

A TABLE of the Equation of natural Days, ſhewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The Biſſextile, or Leap-year.

Days	September			Dif.	October			Dif	November			Dif.	December			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Dec.				Dec.				Inc.
1	11	59	33	19	11	49	28	18	11	43	49	1	11	49	42	24
2	11	59	14	19	11	49	10	18	11	43	48	Inc.	11	50	6	24
3	11	58	55	19	11	48	52	18	11	43	49	1	11	50	30	25
4	11	58	36	19	11	48	34	18	11	43	50	2	11	50	55	25
5	11	58	17		11	48	16		11	43	52		11	51	20	
				20				17				3				26
6	11	57	57	20	11	47	59	17	11	43	55	4	11	51	46	26
7	11	57	37	20	11	47	42	16	11	43	59	5	11	52	12	26
8	11	57	17	20	11	47	26	15	11	44	4	6	11	52	38	27
9	11	56	57	21	11	47	11	15	11	44	10	6	11	53	5	28
10	11	56	36		11	46	56		11	44	16		11	53	33	
				21				15				7				28
11	11	56	15	21	11	46	41	15	11	44	23	8	11	54	1	29
12	11	55	54	21	11	46	26	14	11	44	31	9	11	54	30	29
13	11	55	33	21	11	46	12	13	11	44	40	10	11	54	59	29
14	11	55	12	21	11	45	59	13	11	44	50	11	11	55	28	29
15	11	54	51		11	45	46		11	45	1		11	55	57	
				21				12				12				29
16	11	54	30	20	11	45	34	11	11	45	13	13	11	56	26	30
17	11	54	10	21	11	45	23	11	11	45	26	13	11	56	56	30
18	11	53	49	21	11	45	12	11	11	45	39	14	11	57	26	30
19	11	53	28	21	11	45	1	10	11	45	53	15	11	57	56	30
20	11	53	7		11	44	51		11	46	8		11	58	26	
				21				9				16				30
21	11	52	46	21	11	44	42	9	11	46	24	16	11	58	56	30
22	11	52	25	20	11	44	33	8	11	46	40	17	11	59	26	30
23	11	52	5	20	11	44	25	7	11	46	57	18	11	59	56	30
24	11	51	45	20	11	44	18	7	11	47	15	19	12	0	26	30
25	11	51	25		11	44	11		11	47	34		12	0	56	
				20				6				20				30
26	11	51	5	20	11	44	5	5	11	47	54	20	12	1	26	30
27	11	50	45	20	11	44	0	4	11	48	14	21	12	1	56	29
28	11	50	25	19	11	43	56	3	11	48	35	22	12	2	25	29
29	11	50	6	19	11	43	53	2	11	48	57	22	12	2	54	29
30	11	49	47		11	43	51		11	49	10		12	3	23	
				19				1				23				29
31					11	43	50	1					12	3	57	
	Decr. 9′ 46″				Decr. 5′ 38″				Decr. 0′ 1″ Incr. 5 30				Incr. 14′ 10″			

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The first after Leap-year.

Days	January			Dif.	February			Dif.	March			Dif.	April			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Inc.				Inc.				Dec.				Dec.
1	12	4	21	28	12	14	11	7	12	12	39	13	12	3	52	18
2	12	4	49	27	12	14	1[illegible]	6	12	12	26	13	12	3	34	18
3	12	5	1	27	12	14	2[illegible]	5	12	12	13	13	12	3	16	18
4	12	5	4[illegible]	27	12	14	29	5	12	12	0	14	12	2	5[illegible]	18
5	12	6	10		12	14	34		12	11	46		12	2	40	
				27				4				14				18
6	12	6	37	26	12	14	38	3	12	11	32	15	12	2	22	18
7	12	7	3	25	12	14	41	2	12	11	17	15	12	2	4	17
8	12	7	28	25	12	14	43	1	12	11	2	16	12	1	47	17
9	12	7	53	24	12	14	44	0	12	10	46	16	12	1	30	17
10	12	8	1		12	14	4[illegible]		12	10	30		12	1	13	
				24				Dec.				17				16
11	12	8	4	23	12	14	44	1	12	10	14	17	12	0	57	16
12	12	9	4	22	12	14	4[illegible]	2	12	9	57	17	12	0	41	16
13	12	9	2[illegible]	22	12	14	41	3	12	9	40	17	12	0	25	16
14	12	9	4[illegible]	21	12	14	3[illegible]	3	12	9	23	17	12	0	9	15
15	12	10	9		12	14	35		12	9	6		11	59	54	
				21				4				18				15
16	12	10	30	20	12	14	31	5	12	8	48	18	11	59	39	14
17	12	10	5[illegible]	19	12	14	2[illegible]	6	12	8	30	18	11	59	25	14
18	12	11	[illegible]	18	12	14	20	6	12	8	12	18	11	59	11	14
19	12	11	2[illegible]	17	12	14	14	7	12	7	54	18	11	58	57	13
20	12	11	44		12	14	7		12	7	36		11	58	44	
				17				7				18				13
21	12	12	1	16	12	14	[illegible]	8	12	7	18	19	11	58	31	12
22	12	12	17	15	12	13	52	9	12	6	59	19	11	58	19	12
23	12	12	3[illegible]	14	12	13	43	9	12	6	40	19	11	58	7	12
24	12	12	46	13	12	13	34	10	12	6	21	19	11	57	55	11
25	12	12	5[illegible]		12	13	24		12	6	2		11	57	44	
				13				10				19				10
26	12	13	1[illegible]	12	12	13	14	11	12	5	43	19	11	57	34	10
27	12	13	2[illegible]	11	12	13	3	12	12	5	24	19	11	57	24	10
28	12	13	3[illegible]	10	12	12	51	12	12	5	5	19	11	57	14	9
29	12	13	4[illegible]	9					12	4	46	18	11	57	5	8
30	12	13	5[illegible]						12	4	28		11	56	57	
				9								18				8
31	12	14	3	8					12	4	10	18				

Incr. 9′ 42″ Incr. 0′ 35″ Decr. 1 53 Decr. 8′ 29″ Decr. 6′ 55″

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The first after Leap-year.

Days	May			Dif.	June			Dif	July			Dif	August			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Inc.				Inc.				Dec.
1	11	56	49	8	11	57	1	9	12	3	15	12	12	5	48	4
2	11	56	41	7	11	57	2	9	12	3	27	11	12	5	44	5
3	11	56	34	6	11	57	36	10	12	3	38	11	12	5	39	5
4	11	56	28	6	11	57	46	10	12	3	49	10	12	5	34	6
5	11	56	22	5	11	57	56	10	12	3	59	10	12	5	28	6
6	11	56	17	4	11	58	6	11	12	4	9	10	12	5	22	7
7	11	56	13	4	11	58	17	11	12	4	19	10	12	5	15	7
8	11	56	9	4	11	58	2[illegible]	12	12	4	29	9	12	5	8	8
9	11	56	5	3	11	58	40	12	12	4	38	8	12	5	0	9
10	11	56	2	2	11	58	52	12	12	4	46	8	12	4	51	9
11	11	56	0	2	11	59	4	12	12	4	54	8	12	4	42	10
12	11	55	58	1	11	59	1[illegible]	12	12	5	2	8	12	4	32	10
13	11	55	57	1	11	59	28	12	12	5	10	7	12	4	22	11
14	11	55	56	Inc.	11	59	40	13	12	5	17	6	12	4	11	11
15	11	55	56	1	11	59	53	13	12	5	23	6	12	4	0	12
16	11	55	57	1	12	0	6	13	12	5	29	5	12	3	48	12
17	11	55	58	2	12	0	19	13	12	5	34	5	12	3	36	13
18	11	56	0	2	12	0	32	13	12	5	39	4	12	3	23	13
19	11	56	2	3	12	0	45	13	12	5	43	4	12	3	10	14
20	11	56	5	3	12	0	58	13	12	5	47	4	12	2	56	14
21	11	56	8	4	12	1	11	13	12	5	51	3	12	2	42	15
22	11	56	12	4	12	1	24	13	12	5	54	2	12	2	17	15
23	11	56	16	5	12	1	37	13	12	5	56	1	12	2	12	16
24	11	56	21	6	12	1	50	13	12	5	57	1	12	1	56	16
25	11	56	27	6	12	2	3	13	12	5	58	Dec.	12	1	40	16
26	11	56	33	6	12	2	16	12	12	5	59	1	12	1	24	17
27	11	56	39	7	12	2	28	12	12	5	58	1	12	1	7	17
28	11	56	46	7	12	2	40	12	12	5	57	2	12	1	50	18
29	11	56	53	8	12	2	52	12	12	5	55	2	12	1	32	18
30	11	57	1	8	12	3	4	11	12	5	53	2	12	0	14	18
31	11	57	9	9					12	5	51	3	11	59	56	18

Decr. 0′ 53″ Incr 5′ 46″ Incr. 2′ 43″ Decr. 5′ 52″

Incr. 1 12 Decr. 0 8

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The first after Leap-year.

Days	September H.	M.	S.	Dif. S.	October H.	M.	S.	Dif. S.	November H.	M.	S.	Dif. S.	December H.	M.	S.	Dif. S.
				Dec.				Dec.				Dec.				Inc.
1	11	59	38	19	11	49	33	19	11	43	49	0	11	49	36	24
2	11	59	19	19	11	49	14	19	11	43	49	Inc.	11	50	0	24
3	11	59	0	19	11	48	5	18	11	43	49	1	11	50	24	25
4	11	58	41	20	11	48	37	17	11	43	50	2	11	50	49	25
5	11	58	21		11	48	2[illegible]		11	43	52		11	51	14	
—				20				17				3				26
6	11	58	1	20	11	48	3	17	11	43	55	3	11	51	40	26
7	11	57	41	20	11	47	46	17	11	43	58	4	11	52	6	27
8	11	57	21	20	11	47	29	16	11	44	2	5	11	52	33	27
9	11	57	1	20	11	47	13	15	11	44	7	6	11	53	0	27
10	11	56	41		11	46	58		11	44	13		11	53	27	
—				20				15				7				28
11	11	56	21	21	11	46	4[illegible]	14	11	44	20	8	11	53	35	28
12	11	56	0	21	11	46	29	13	11	44	28	9	11	54	23	29
13	11	55	39	21	11	46	16	13	11	44	37	10	11	54	52	29
14	11	55	18	21	11	46	3	13	11	44	47	11	11	55	21	29
15	11	54	57		11	45	50		11	44	58		11	55	50	
—				21				13				12				30
16	11	54	36	21	11	45	37	12	11	45	10	13	11	56	19	30
17	11	54	15	21	11	45	25	11	11	45	23	13	11	56	49	30
18	11	53	54	21	11	45	14	11	11	45	36	14	11	57	19	30
19	11	53	33	21	11	45	3	10	11	45	50	14	11	57	49	30
20	11	53	12		11	44	53		11	46	4		11	58	19	
—				21				10				15				30
21	11	52	51	20	11	44	43	9	11	46	19	16	11	58	49	30
22	11	52	31	20	11	44	34	8	11	46	35	17	11	59	19	30
23	11	52	11	21	11	44	26	7	11	46	52	18	11	59	49	30
24	11	51	50	21	11	44	19	6	11	47	10	19	12	0	1[illegible]	30
25	11	51	29		11	44	13		11	47	29		12	0	4[illegible]	
—				20				6				19				30
26	11	51	9	20	11	44	7	5	11	47	48	20	12	1	19	30
27	11	50	49	19	11	44	2	4	11	48	8	21	12	1	49	29
28	11	50	30	19	11	43	58	3	11	48	29	22	12	2	18	29
29	11	50	11	19	11	43	55	3	11	48	51	22	12	2	47	29
30	11	49	52		11	43	52		11	49	13		12	3	16	
—				19				2				23				29
31					11	43	50	1					12	3	45	29
	Decr. 9′ 46″				Decr. 5′ 43″				Decr. 0′ 0″ Incr. 5 24				Incr. 14′ 9″			

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The second after Leap-year.

Days	January			Dif.	February			Dif.	March			Dif.	April			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S	S.
				Inc.				Dec.				Inc.				Dec.
1	12	4	14	28	12	14	9	7	12	12	42	13	12	3	56	18
2	12	4	42	28	12	14	16	6	12	12	29	13	12	3	38	18
3	12	5	10	27	12	14	22	5	12	12	16	13	12	3	20	18
4	12	5	37	27	12	14	27	5	12	12	3	14	12	3	2	18
5	12	6	4		12	14	32		12	11	49		12	2	44	
				27				4				14				18
6	12	6	30	26	12	14	36	3	12	11	35	15	12	2	26	17
7	12	6	56	26	12	14	39	2	12	11	20	15	12	2	9	17
8	12	7	22	25	12	14	41	2	12	11	5	15	12	1	52	17
9	12	7	47	24	12	14	43	1	12	10	50	16	12	1	35	17
10	12	8	11		12	14	44		12	10	34		12	1	18	
				24				Dec.				16				17
11	12	8	35	23	12	14	44	1	12	10	18	17	12	1	1	16
12	12	8	58	22	12	14	43	2	12	10	1	17	12	0	45	16
13	12	9	20	22	12	14	41	3	12	9	44	17	12	0	29	16
14	12	9	42	21	12	14	38	3	12	9	27	17	12	0	13	15
15	12	10	3		12	14	35		12	9	10		11	59	58	
				21				4				18				15
16	12	10	24	20	12	14	31	4	12	8	52	18	11	59	43	14
17	12	10	44	19	12	14	27	5	12	8	34	18	11	59	29	14
18	12	11	3	18	12	14	22	6	12	8	16	18	11	59	15	14
19	12	11	21	18	12	14	16	7	12	7	58	18	11	59	1	14
20	12	11	39		12	14	9		12	7	40		11	58	47	
				17				7				18				13
21	12	11	56	16	12	14	2	8	12	7	22	18	11	58	34	12
22	12	12	12	15	12	13	54	9	12	7	4	19	11	58	22	12
23	12	12	27	15	12	13	45	9	12	6	45	19	11	58	10	12
24	12	12	42	14	12	13	36	10	12	6	26	19	11	57	58	11
25	12	12	56		12	13	26		12	6	7		11	57	47	
				13				10				19				11
26	12	13	9	12	12	13	16	11	12	5	48	19	11	57	36	10
27	12	13	21	11	12	13	5	11	12	5	29	19	11	57	26	10
28	12	13	32	10	12	12	54	12	12	5	10	19	11	57	16	9
29	12	13	42	10					12	4	51	18	11	57	7	9
30	12	13	52						12	4	33		11	56	58	
				9								18				8
31	12	14	1	8					12	4	15	18				

Incr. 9′ 47″ Incr. 0′ 35″ Decr. 1 50 Decr. 8′ 27″ Decr. 6′ 58″

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The second after Leap-year.

Days	May			Dif.	June			Dif.	July			Dif.	August			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec				Inc.				Inc.				Dec.
1	11	56	50	8	11	57	16	9	12	3	12	12	12	5	48	4
2	11	56	42	7	11	57	25	10	12	3	24	11	12	5	44	4
3	11	56	35	6	11	57	35	10	12	3	35	11	12	5	40	5
4	11	56	29	6	11	57	45	10	12	3	46	11	12	5	35	5
5	11	56	23		11	57	55		12	3	57		12	5	30	
				5				10				10				6
6	11	56	19	5	11	58	5	11	12	4	7	10	12	5	24	7
7	11	56	13	4	11	58	16	11	12	4	17	9	12	5	17	7
8	11	56	9	3	11	58	27	11	12	4	26	9	12	5	10	8
9	11	56	6	3	11	58	38	12	12	4	35	9	12	5	2	9
10	11	56	3		11	58	50		12	4	46		12	4	53	
				2				12				8				9
11	11	56	1	2	11	59	2	12	12	4	52	8	12	4	44	9
12	11	55	5[illegible]	2	11	59	14	12	12	5	0	8	12	4	35	10
13	11	55	57	1	11	59	26	12	12	5	8	7	12	4	25	11
14	11	55	50	Inc.	11	59	38	12	12	5	15	6	12	4	14	11
15	11	55	56		11	59	50		12	5	21		12	4	3	
				1				13				6				12
16	11	55	57	1	12	0	3	13	12	5	27	6	12	3	51	12
17	11	55	58	2	12	0	16	13	12	5	33	5	12	3	39	12
18	11	56	0	2	12	0	29	13	12	5	38	4	12	3	27	13
19	11	56	2	3	12	0	42	13	12	5	42	4	12	3	14	14
20	11	56	5		12	0	55		12	5	46		12	3	0	
				3				13				3				14
21	11	56	8	3	12	1	8	13	12	5	49	3	12	2	46	15
22	11	56	11	4	12	1	21	13	12	5	52	2	12	2	31	15
23	11	56	15	5	12	1	34	13	12	5	54	2	12	2	16	15
24	11	56	20	6	12	1	47	12	12	5	56	2	12	2	1	16
25	11	56	26		12	1	59		12	5	58		12	1	45	
				6				13				1				16
26	11	56	32	6	12	2	12	13	12	5	59	Dec	12	1	29	17
27	11	56	38	7	12	2	25	12	12	5	58	1	12	1	12	17
28	11	56	45	7	12	2	37	12	12	5	57	1	12	0	55	18
29	11	56	52	8	12	2	49	12	12	5	56	2	12	0	37	18
30	11	57	0		12	3	1		12	5	54		12	0	19	
				8				11				3				18
31	11	57	8	8					12	5	51	3	12	0	1	18

May	June	July	August
Decr. 0′ 54″	Incr. 5′ 45″	Incr. 2′ 46″	Decr. 5′ 47″
Incr. 1 12		Decr. 0 8	

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The second after Leap-year.

Days	September			Dif.	October			Dif.	November			Dif.	December			Dif.
	H.	M.	S.	S.	H.	M.	S	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Dec.				Dec.				Inc
1	11	59	43	19	11	49	37	19	11	43	49	1	11	49	30	23
2	11	59	24	19	11	49	18	18	11	43	48	Inc	11	49	53	24
3	11	59	5	19	11	49	0	18	11	43	49	1	11	50	17	25
4	11	58	46	20	11	48	42	18	11	43	50	2	11	50	42	25
5	11	58	26		11	48	24		11	43	52		11	51	7	
				20				17				3				26
6	11	58	6	20	11	48	7	17	11	43	55	3	11	51	33	26
7	11	57	46	20	11	47	50	17	11	43	58	4	11	51	59	26
8	11	57	26	21	11	47	33	16	11	44	2	5	11	52	25	27
9	11	57	5	20	11	47	17	16	11	44	7	6	11	52	52	28
10	11	56	45		11	47	1		11	44	13		11	53	20	
				21				15				7				28
11	11	56	24	21	11	46	46	14	11	44	20	8	11	53	48	28
12	11	56	3	21	11	46	32	14	11	44	28	9	11	54	16	28
13	11	55	42	20	11	46	18	13	11	44	37	9	11	54	44	29
14	11	55	22	20	11	46	5	13	11	44	46	10	11	54	13	29
15	11	55	2		11	45	52		11	44	56		11	55	42	
				21				13				11				29
16	11	54	41	21	11	45	39	12	11	45	7	12	11	56	11	30
17	11	54	20	21	11	45	27	11	11	45	19	13	11	56	41	30
18	11	53	59	20	11	45	16	10	11	45	32	14	11	57	11	30
19	11	53	39	21	11	45	6	10	11	45	46	15	11	57	41	30
20	11	53	18		11	44	56		11	46	1		11	58	11	
				21				10				15				30
21	11	52	57	20	11	44	46	9	11	46	16	16	11	58	41	30
22	11	52	37	21	11	44	37	8	11	46	32	17	11	59	11	30
23	11	52	16	21	11	44	29	7	11	46	49	18	11	59	41	30
24	11	51	55	21	11	44	22	7	11	47	7	18	12	0	11	30
25	11	51	34		11	44	15		11	47	25		12	0	41	
				20				6				19				30
26	11	51	14	20	11	44	9	5	11	47	44	20	12	1	11	30
27	11	50	54	20	11	44	4	5	11	48	4	21	12	1	41	30
28	11	50	34	19	11	43	59	4	11	48	25	21	12	2	11	29
29	11	50	15	19	11	43	55	3	11	48	46	22	12	2	40	29
30	11	49	56		11	43	52		11	49	8		12	3	9	
				19				2				22				29
31					11	43	51	1					12	3	38	29

Decr. 9′ 47″ Decr. 5′ 47″ Decr. 0′ 1″ Incr. 5 19 Incr. 14′ 8″

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The third after Leap-year.

Days	January			Dif	February			Dif.	March			Dif.	April			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Inc.				Inc.				Dec.				Dec.
1	12	4	7	28	12	14	6	7	12	12	44	12	12	4	1	18
2	12	4	35	28	12	14	13	7	12	12	32	13	12	3	43	18
3	12	5	3	27	12	14	20	6	12	12	19	13	12	3	25	18
4	12	5	30	27	12	14	26	5	12	12	6	14	12	3	7	18
5	12	5	57		12	14	31		12	11	52		12	2	49	
				27				4				14				18
6	12	6	24	26	12	14	35	3	12	11	38	14	12	2	31	18
7	12	6	50	25	12	14	38	2	12	11	24	15	12	2	13	18
8	12	7	15	25	12	14	41	1	12	11	9	16	12	1	55	17
9	12	7	40	25	12	14	43	1	12	10	53	16	12	1	38	17
10	12	8	5		12	14	44		12	10	37		12	1	21	
				24				Dec.				16				16
11	12	8	59	23	12	14	44	1	12	10	21	16	12	1	5	16
12	12	8	52	23	12	14	43	2	12	10	5	17	12	0	49	16
13	12	9	15	22	12	14	41	2	12	10	48	17	12	0	33	16
14	12	9	37	21	12	14	39	3	12	9	31	17	12	0	17	15
15	12	9	58		12	14	36		12	9	14		12	0	2	
				21				4				17				15
16	12	10	19	20	12	14	32	4	12	8	57	18	11	59	47	15
17	12	10	39	19	12	14	28	5	12	8	39	18	11	59	32	14
18	12	10	58	18	12	14	23	6	12	8	21	18	11	59	18	14
19	12	11	16	18	12	14	17	7	12	8	3	18	11	59	4	14
20	12	11	34		12	14	10		12	7	45		11	58	50	
				17				7				18				13
21	12	11	51	16	12	14	3	8	12	7	27	19	11	58	37	13
22	12	12	7	16	12	13	55	8	12	7	8	19	11	58	24	12
23	12	12	23	15	12	13	47	9	12	6	49	19	11	58	12	12
24	12	12	38	14	12	13	38	9	12	6	30	19	11	58	0	11
25	12	12	52		12	13	29		12	6	11		11	57	49	
				13				10				18				11
26	12	13	5	12	12	13	19	11	12	5	53	19	11	57	38	10
27	12	13	17	11	12	13	8	12	12	5	34	19	11	57	28	10
28	12	13	28	11	12	12	56	12	12	5	15	18	11	57	18	9
29	12	13	39	10					12	4	57	19	11	57	9	9
30	12	13	49						12	4	38		11	57	0	
				9								19				8
31	12	13	58	8					12	4	19	18				

Incr. 9′ 51″ — Incr. 0′ 38″, Decr. 1 48 — Decr. 8′ 25″ — Decr. 7′ 1″

A TABLE

A TABLE of the Equation of natural Days, shewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The third after Leap-year.

Days	May			Dif	June			Dif	July			Dif.	August			Dif.
	H.	M.	S.	S.	H.	M	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Inc.				Inc.				Dec.
1	11	56	52	8	11	57	15	9	12	3	10	11	12	5	49	4
2	11	56	44	7	11	57	24	9	12	3	21	11	12	5	45	4
3	11	56	37	7	11	57	33	9	12	3	32	11	12	5	41	5
4	11	56	30	6	11	57	42	10	12	3	43	11	12	5	36	5
5	11	56	24		11	57	52		12	3	54		12	5	31	
				5				10				10				6
6	11	56	19	5	11	58	2	11	12	4	4	10	12	5	25	7
7	11	56	14	4	11	58	15	11	12	4	14	10	12	5	18	7
8	11	56	10	4	11	58	24	11	12	4	24	9	12	5	11	7
9	11	56	6	3	11	58	35	11	12	4	33	9	12	5	4	8
10	11	56	3		11	58	46		12	4	42		12	4	56	
				2				12				8				9
11	11	56	1	2	11	58	58	12	12	4	50	8	12	4	47	9
12	11	55	59	2	11	59	10	12	12	4	58	8	12	4	37	10
13	11	55	57	1	11	59	22	12	12	5	6	7	12	4	27	10
14	11	55	56	Inc.	11	59	34	13	12	5	13	6	12	4	17	11
15	11	55	56		11	59	47		12	5	19		12	4	6	
				1				13				6				12
16	11	55	57	1	12	0	0	13	12	5	25	6	12	3	54	12
17	11	55	58	1	12	0	13	13	12	5	31	5	12	3	42	13
18	11	55	59	2	12	0	26	13	12	5	36	5	12	3	29	13
19	11	56	1	2	12	0	39	13	12	5	41	4	12	3	16	13
20	11	56	3		12	0	52		12	5	45		12	3	3	
				3				13				4				14
21	11	56	6	4	12	1	5	12	12	5	49	3	12	2	49	15
22	11	56	10	4	12	1	17	13	12	5	52	3	12	2	34	15
23	11	56	14	5	12	1	30	13	12	5	55	2	12	2	19	15
24	11	56	19	5	12	1	43	13	12	5	57	1	12	2	4	16
25	11	56	24		12	1	56		12	5	58		12	1	48	
				6				13				1				16
26	11	56	30	6	12	2	9	13	12	5	59	Dec.	12	1	32	16
27	11	56	36	7	12	2	22	12	12	5	58	1	12	1	16	17
28	11	56	43	7	12	2	34	12	12	5	57	1	12	0	59	17
29	11	56	50	8	12	2	46	12	12	5	56	2	12	0	42	18
30	11	56	58		12	2	58		12	5	54		12	0	24	
				8				12				2				18
31	11	57	6	9					12	5	52	3	12	0	6	19

May	June	July	August
Decr. 0′ 56″	Incr. 5′ 43″	Incr. 2′ 48″	Incr. 5′ 43″
Incr. 1 10		Decr. 0 7	

A TABLE

A TABLE of the Equation of natural Days, ſhewing what Time it ought to be by the Clock when the Sun is on the Meridian.

The third after Leap-year.

Days	September			Dif.	October			Dif.	November			Dif.	December			Dif.
	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.	H.	M.	S.	S.
				Dec.				Dec.				Dec.				Inc.
1	11	59	47	19	11	49	42	18	11	43	49	1	11	49	25	23
2	11	59	28	19	11	49	24	18	11	43	48	Inc	11	49	48	24
3	11	59	9	19	11	49	6	18	11	43	48	1	11	50	12	24
4	11	58	50	19	11	48	48	18	11	43	49	2	11	50	36	25
5	11	58	31		11	48	30		11	43	51		11	51	1	
				20				18				2				25
6	11	58	11	20	11	48	12	17	11	43	53	3	11	51	26	26
7	11	57	51	20	11	47	55	16	11	43	56	4	11	51	52	27
8	11	57	31	20	11	47	39	16	11	44	0	5	11	52	19	27
9	11	57	11	20	11	47	23	16	11	44	5	6	11	52	46	27
10	11	56	51		11	47	7		11	44	11		11	53	13	
				20				15				7				28
11	11	56	31	21	11	46	52	15	11	44	18	8	11	53	41	28
12	11	56	10	21	11	46	37	14	11	44	26	8	11	54	8	28
13	11	55	49	21	11	46	23	14	11	44	34	9	11	54	37	29
14	11	55	28	21	11	46	9	13	11	44	43	10	11	55	6	30
15	11	55	7		11	45	56		11	44	53		11	55	36	
				20				12				11				29
16	11	54	47	21	11	45	44	12	11	45	4	12	11	56	6	30
17	11	54	26	21	11	45	32	12	11	45	16	13	11	56	36	30
18	11	54	5	21	11	45	20	11	11	45	29	14	11	57	6	29
19	11	53	44	21	11	45	9	10	11	45	43	14	11	57	35	30
20	11	53	23		11	44	59		11	45	57		11	58	5	
				20				9				15				30
21	11	53	3	21	11	44	50	9	11	46	12	16	11	58	34	30
22	11	52	42	21	11	44	41	9	11	46	28	17	11	59	4	30
23	11	52	21	20	11	44	32	8	11	46	45	17	11	59	31	30
24	11	52	1	21	11	44	24	7	11	47	2	18	12	0	4	30
25	11	51	40		11	44	17		11	47	20		12	0	34	
				20				6				19				30
26	11	51	20	20	11	44	11	5	11	47	39	20	12	1	4	30
27	11	51	0	20	11	44	6	5	11	47	59	20	12	1	34	30
28	11	50	40	20	11	44	1	4	11	48	19	21	12	2	4	29
29	11	50	20	19	11	43	57	3	11	48	40	22	12	2	33	29
30	11	50	1		11	43	54		11	49	2		12	3	2	
				19				3				23				29
31					11	43	51	2					12	3	31	29

Decr. 9′ 46″ Decr. 5′ 51″ Decr. 0′ 1″ Incr. 5 14 Incr. 14′ 6″

CHAP.

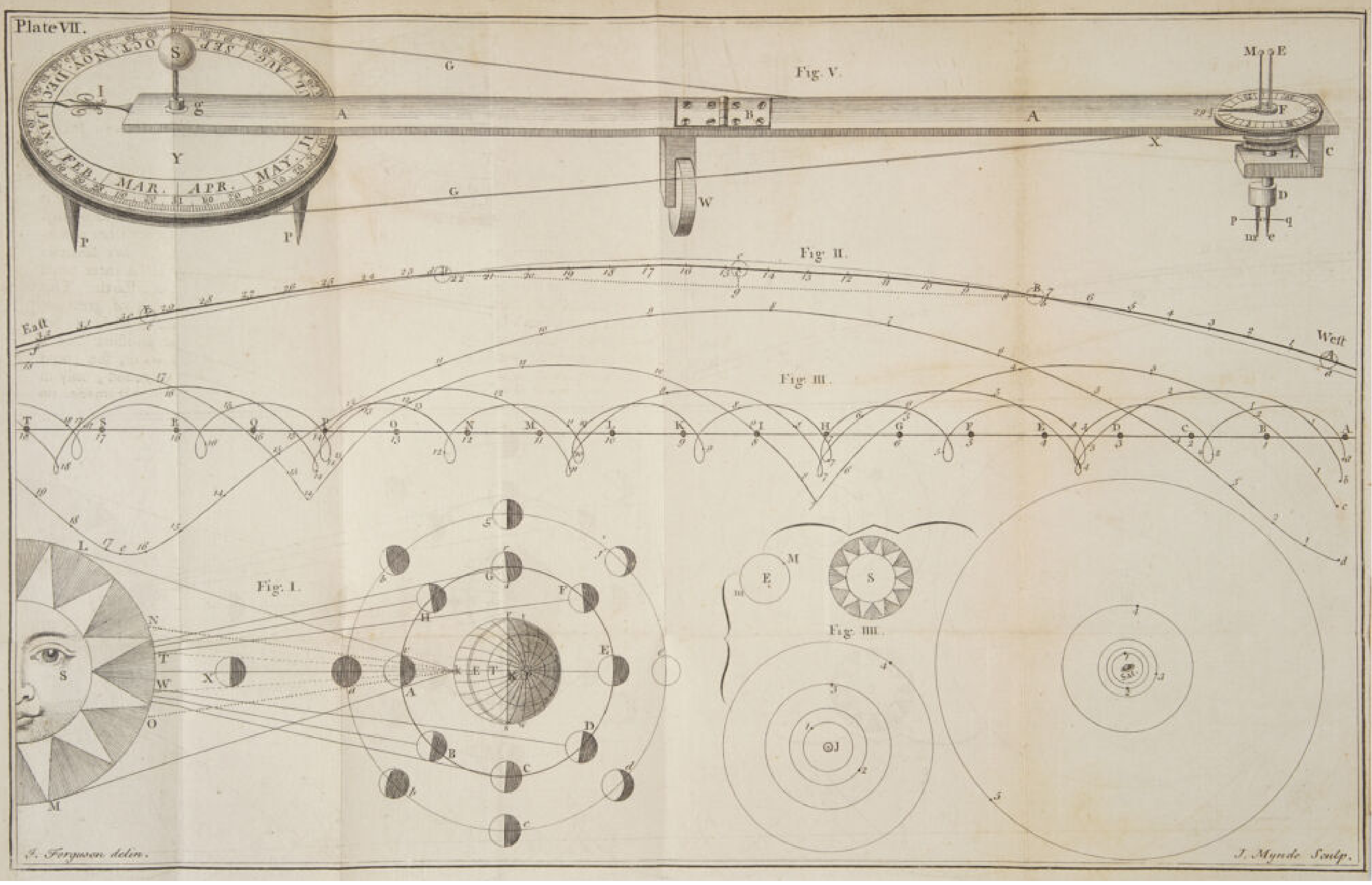


Plate VII.
Fig. V.
JAN.
FEB.
MAR.
APR.
MAY.
AUG.
SEP.
OCT.
NOV.
DEC.
Fig. II.
East
West
Fig. III.
Fig. I.
Fig. IIII.
J. Ferguson delin.
J. Mynde Sculp.

CHAP. XV.

The Moon's ſurface mountainous: Her Phaſes deſcribed: Her path, and the paths of Jupiter's Moons delineated: The proportions of the Diameters of their Orbits, and thoſe of Saturn's Moons, to each other; and to the Diameter of the Sun.

252. BY looking at the Moon with an ordinary telescope, we perceive that her ſurface is diverſified with long tracts of prodigious high mountains and deep cavities. Some of her mountains, by comparing their height with her diameter (which is 2180 miles) are found to be three times higher than the higheſt hills on our Earth. This ruggedneſs of the Moon's ſurface is of great uſe to us, by reflecting the Sun's light to all ſides: for if the Moon were ſmooth and poliſhed like a looking-glaſs, or covered with water, ſhe could never diſtribute the Sun's light all round; only in ſome poſitions ſhe would ſhew us his image, no bigger than a point, but with ſuch a luſtre as would be hurtful to our eyes. PLATE VII. The Moon's ſurface mountainous.

253. The Moon's ſurface being ſo uneven, many have wondered why her edge appears not jagged, as well as the curve bounding the light and dark places. But if we conſider, that what we call the edge of the Moon's Diſc is not a ſingle line ſet round with mountains, in which caſe it would appear irregularly indented, but a large Zone having many mountains lying behind one another from the obſerver's eye, we ſhall find that the mountains in ſome rows will be oppoſite to the vales in others; and ſo fill up the inequalities as to make her appear quite round: juſt as when one looks at an orange, although it's roughneſs be very diſcernible on the ſide next the eye, eſpecially if the Sun or a Candle ſhines obliquely on that ſide, yet the line terminating Why no hills appear on her edge.

PLATE VII. terminating the visible part still appears smooth and even.

The Moon has no twilight. 254. As the Sun can only enlighten that half of the Earth which is at any moment turned towards him, and being withdrawn from the opposite half, leaves it in darkness; so he likewise doth to the Moon: only with this difference, that the Earth being surrounded by an Atmosphere, and the Moon having none, we have twilight after the Sun sets; but the Lunar inhabitants have an immediate transition from the brightest Sun-shine to the blackest darkness, § 177. For, let *t r k s w* be the Earth, and *A,B,C,D,E,F,G,H* the Moon in eight different parts of her Orbit. As the Earth turns round its Axis, from west to east, when any place comes to *t* the twilight begins there, and when it revolves from thence to *r* the Sun *S* rises; when the place comes to *s* the Sun sets, and when it comes to *w* the twilight ends. But as the Moon turns round her Axis, which is only once a month, the moment that any point of her surface comes to *r* (see the Moon at *G*) the Sun rises there without any previous warning by twilight; and when the same point comes to *s* the Sun sets, and that point goes into darkness as black as at midnight.

Fig. I.

The Moon's Phases. 255. The Moon being an opaque spherical body (for her hills take off no more from her roundness than the inequalities on the surface of an orange takes off from it's roundness) we can only see that part of the enlightened half of her which is towards the Earth. And therefore, when the Moon is at *A*, in conjunction with the Sun *S*, her dark half is towards the Earth, and she disappears, as at *a*, there being no light on that half to render it visible. When she comes to her first Octant at *B*, or has gone an eighth part of her Orbit from her Conjunction, a quarter of her enlightened side is towards the Earth, and she appears horned, as at *b*. When she has gone a quarter of her Orbit from between the Earth and Sun to *C*, she shews us us one half of her enlightened ſide, as at *c*, and we ſay, ſhe is a quarter old. At *D* ſhe is in her ſecond Octant, and by ſhewing us more of her enlightened ſide ſhe appears gibbous, as at *d*. At *E* her whole enlightened ſide is towards the Earth, and therefore ſhe appears round, as at *e*, when we ſay, It is full Moon. In her third Octant at *F*, part of her dark ſide being towards the Earth, ſhe again appears gibbous, and is on the decreaſe, as at *f*. At *G* we ſee juſt one half of her enlightened ſide, and ſhe appears half decreaſed, or in her third Quarter, as at *g*. At *H* we only ſee a quarter of her enlightened ſide, being in her fourth Octant, where ſhe appears horned, as at *h*. And at *A*, having compleated her courſe from the Sun to the Sun again, ſhe diſappears; and we ſay, it is New Moon. Thus in going from *A* to *E* the Moon ſeems continually to increaſe; and in going from *E* to *A*, to decreaſe in the ſame proportion; having like Phaſes at equal diſtances from *A* or *E*, but as ſeen from the Sun *S*, ſhe is always Full.

The Moon's Diſc not always quite round when full.

256. The Moon appears not perfectly round when ſhe is Full in the higheſt or loweſt part of her Orbit, becauſe we have not a full view of her enlightened ſide at that time. When Full in the higheſt part of her Orbit, a ſmall deficiency appears on her lower edge; and the contrary when Full in the loweſt part of her Orbit.

The Phaſes of the Earth and Moon contrary.

257. It is plain by the Figure, that when the Moon changes to the Earth, the Earth appears Full to the Moon; and *vice verſa.* For when the Moon is at *A*, *New* to the Earth, the whole enlightened ſide of the Earth is towards the Moon: and when the Moon is at *E*, *Full* to the Earth, it's dark ſide is towards her. Hence a *New Moon* anſwers to a *Full Earth*, and a *Full Moon* to a *New Earth.* The *Quarters* are alſo reverſed to each other.

An agreeable Phenomenon.

258. Between the third Quarter and Change, the Moon is frequently viſible in the forenoon, even

when the Sun ſhines; and then ſhe affords us an opportunity of ſeeing a very agreeable appearance, wherever we find a globular ſtone above the level of the eye, as ſuppoſe on the top of a gate. For, if the Sun ſhines on the ſtone, and we place ourſelves ſo as the upper part of the ſtone may juſt ſeem to touch the point of the Moon's lowermoſt horn, we ſhall then ſee the enlightened part of the ſtone exactly of the ſame ſhape with the Moon; horned as ſhe is, and inclining the ſame way to the Horizon. The reaſon is plain; for the Sun enlightens the ſtone the ſame way as he does the Moon: and both being Globes, when we put ourſelves into the above ſituation, the Moon and ſtone have the ſame poſition to our eyes; and therefore we muſt ſee as much of the illuminated part of the one as of the other.

The Nonageſimal Degree, what.

259. The poſition of the Moon's Cuſps, or a right line touching the points of her horns, is very differently inclined to the Horizon at different hours of the ſame days of her age. Sometimes ſhe ſtands, as it were, upright on her lower horn, and then ſuch a line is perpendicular to the Horizon: when this happens, ſhe is in what the Aſtronomers call *the Nonageſimal Degree*; which is the higheſt point of the Ecliptic above the Horizon at that time, and is 90 degrees from both ſides of the Horizon where it is then cut by the Ecliptic. But this never happens when the Moon is on the Meridian, except when ſhe is at the very beginning of Cancer or Capricorn.

How the inclination of the Ecliptic may be found by the poſition of the Moon's horns.

260. The inclination of that part of the Ecliptic to the Horizon in which the Moon is at any time when horned, may be known by the poſition of her horns; for a right line touching their points is perpendicular to the Ecliptic. And as the angle that the Moon's Orbit makes with the Ecliptic can never raiſe her above, nor depreſs her below the Ecliptic, more than two minutes of a degree, as ſeen from the Sun; it can have no ſenſible

fenfible effect upon the pofition of her horns. Therefore, if a Quadrant be held up, fo as one of it's edges may feem to touch the Moon's horns, the graduated fide being kept towards the eye, and as far from the eye as it can be conveniently held, the arc between the Plumb-line and that edge of the Quadrant which feems to touch the Moon's horns will fhew the inclination of that part of the Ecliptic to the Horizon. And the arc between the other edge of the Quadrant and Plumb-line will fhew the inclination of the Moon's horns to the Horizon.

PLATE VII.

Fig. I. Why the Moon appears as big as the Sun.

261. The Moon generally appears as large as the Sun; for the Angle *vkA*, under which the Moon is feen from the Earth, is the fame with the Angle *LkM*, under which the Sun is feen from it. And therefore the Moon may hide the Sun's whole Difc from us, as fhe fometimes does in folar Eclipfes. The reafon why fhe does not eclipfe the Sun at every Change fhall be explained afterwards. If the Moon were farther from the Earth, as at *a*, fhe could never hide the whole of the Sun from us; for then fhe would appear under the Angle *NkO*, eclipfing only that part of the Sun which lies between *N* and *O*: were fhe ftill further from the Earth, as at *X*, fhe would appear under the fmall angle *TkW*, like a fpot on the Sun, hiding only the part *TW* from our fight.

A proof of the Moon's turning round her Axis.

262. The Moon turns round her Axis in the time that fhe goes round her Orbit; which is evident from hence, that a fpectator at reft, without the periphery of the Moon's Orbit, would fee all her fides turned regularly towards him in that time. She turns round her Axis from any Star to the fame Star again in 27 days 8 hours; from the Sun to the Sun again in 29½ days: the former is the length of her fydereal day, and the latter the length of her folar day. A body moving round the Sun would have a folar day in every revolution, without turning on it's Axis; the fame as if it

N had

had kept all the while at rest, and the Sun moved round it: but without turning round it's Axis it could never have one sydereal day, because it would always keep the same side towards any given Star.

Her periodical and synodical Revolution.

263. If the Earth had no annual motion, the Moon would go round it so as to compleat a Lunation, a sydereal, and a solar day, all in the same time. But, because the Earth goes forward in it's Orbit while the Moon goes round the Earth in her Orbit, the Moon must go as much more than round her Orbit from Change to Change in compleating a solar day, as the Earth has gone forward in it's Orbit during that time, *i. e.* almost a twelfth part of a Circle.

Familiarly represented.

264. The Moon's periodical and synodical revolution may be familiarly represented by the motions of the hour and minute hands of a watch round it's dial-plate, which is divided into 12 equal parts or hours, as the Ecliptic is divided into 12 Signs, and the year into 12 months. Let us suppose these 12 hours to be 12 Signs, the hour-hand the Sun, and the minute-hand the Moon; then the former will go round once in a year, and the latter once in a month; but the Moon, or minute-hand, must go more than round from any

A Table shewing the times that the hour and minute hands of a watch are in conjunction.

Conj.	H.	M.	S.	'''	''''	v p^{ts}.
1	I	5	27	16	21	$49\frac{1}{11}$
2	II	10	54	32	43	$38\frac{2}{11}$
3	III	16	21	49	5	$27\frac{3}{11}$
4	IIII	21	49	5	27	$16\frac{4}{11}$
5	V	27	16	21	49	$5\frac{5}{11}$
6	VI	32	43	38	10	$54\frac{6}{11}$
7	VII	38	10	54	32	$43\frac{7}{11}$
8	VIII	43	38	10	54	$32\frac{8}{11}$
9	IX	49	5	27	16	$21\frac{9}{11}$
10	X	54	32	43	38	$10\frac{10}{11}$
11	XII	0	0	0	0	0

point

point of the Circle where it was laſt conjoined with the Sun, or hour-hand, to overtake it again: for the hour-hand being in motion, can never be overtaken by the minute-hand at that point from which they ſtarted at their laſt conjunction. The firſt column of the preceding Table ſhews the number of conjunctions which the hour and minute-hand make whilſt the hour-hand goes once round the dial-plate; and the other columns ſhew the times when the two hands meet at every conjunction. Thus, ſuppoſe the two hands to be in conjunction at XII, as they always are; then, at the firſt following conjunction it is 5 minutes 27 ſeconds 16 thirds 21 fourths $49\frac{1}{11}$ fifths paſt I where they meet; at the ſecond conjunction it is 10 minutes 54 ſeconds 32 thirds 43 fourths $38\frac{2}{11}$ fifths paſt II; and ſo on. This, though an eaſy illuſtration of the motions of the Sun and Moon, is not preciſe as to the times of their conjunctions; becauſe, while the Sun goes round the Ecliptic, the Moon makes $12\frac{1}{3}$ conjunctions with him; but the minute-hand of a watch or clock makes only 11 conjunctions with the hour-hand in one period round the dial-plate. But if, inſtead of the common wheel-work at the back of the dial-plate, the Axis of the minute-hand had a pinion of 6 leaves turning a wheel of 74, and this laſt turning the hour-hand, in every revolution it makes round the dial-plate, the minute-hand would make $12\frac{1}{3}$ conjunctions with it; and ſo would be a pretty device for ſhewing the motions of the Sun and Moon; eſpecially, as the ſloweſt moving hand might have a little Sun fixed on it's point, and the quickeſt a little Moon. Beſides, the plate, inſtead of hours and quarters, might have a Circle of months, with the 12 Signs and their Degrees; and if a plate of $29\frac{1}{2}$ equal parts for the days of the Moon's age were fixed to the Axis of the Sun-hand, and below it, ſo as the Sun always kept at the half day of that plate, the Moon-hand would ſhew the Moon's

A machine for ſhewing the motions of the Sun and Moon.

age upon that plate for every day pointed out by the Sun-hand in the Circle of months; and both Sun and Moon would ſhew their places in the Ecliptic: for the Sun would go round the Ecliptic in 365 Days; and the Moon in $27\frac{1}{3}$ days, which is her periodical revolution; but from the Sun to the Sun again, or from Change to Change, in $29\frac{1}{2}$ days, which is her ſynodical revolution.

The Moon's motion through open ſpace deſcribed.

265. If the Earth had no annual motion, the Moon's motion round the Earth, and her track in abſolute ſpace, would be always the ſame *. But as the Earth and Moon move round the Sun, the Moon's real path in the Heavens is very different from her viſible path round the Earth: the latter being in a progreſſive Circle, and the former in a curve of different degrees of concavity, which would always be the ſame in the ſame parts of the Heavens, if the Moon performed a compleat number of Lunations in a year without any thing over.

An idea of the Earth's path and the Moon's.

266. Let a nail in the end of the axle of a chariot-wheel repreſent the Earth, and a pin in the nave the Moon; if the body of the chariot be propped up ſo as to keep that wheel from touching the ground, and the wheel be then turned round by hand, the pin will deſcribe a Circle both round the nail and in the ſpace it moves through. But if the props be taken away, the horſes put to, and the chariot driven over a piece of ground which is circularly convex; the nail in the axle will deſcribe a circular curve, and the pin in the nave will ſtill deſcribe a circle round the progreſſive nail in the axle, but not in the ſpace through which it moves. In this caſe, the curve deſcribed by the nail will reſemble in miniature as much of

* In this place, we may conſider the Orbits of all the Satellites as circular, with reſpect to their primary Planets; becauſe the excentricities of their Orbits are too ſmall to affect the Phenomena here deſcribed.

the Earth's annual path round the Sun, as it describes whilst the Moon goes as often round the Earth as the pin does round the nail: and the curve described by the nail will have some resemblance of the Moon's path during so many Lunations. PLATE VII.

Let us now suppose that the radius of the circular curve described by the nail in the axle is to the radius of the circle which the pin in the nave describes round the axle as $337\frac{1}{2}$ to 1; which is the proportion of the radius or semidiameter of the Earth's Orbit to that of the Moon's; or of the circular curve *A* 1 2 3 4 5 6 7 *B* &c. to the little circle *a*; and then, whilst the progressive nail describes the said curve from *A* to *E*, the pin will go once round the nail with regard to the center of it's path, and in doing so, will describe the curve *a b c d e*. The former will be a true representation of the Earth's path for one Lunation, and the latter of the Moon's for that time. Here we may set aside the inequalities of the Moon's motion, and also the Earth's moving round it's common center of gravity and the Moon's: all which, if they were truly copied in this experiment, would not sensibly alter the figure of the paths described by the nail and pin, even though they should rub against a plain upright surface all the way, and leave their tracks visible upon it. And if the chariot was driven forward on such a convex piece of ground, so as to turn the wheel several times round, the track of the pin in the nave would still be concave toward the center of the circular curve described by the pin in the axle; as the Moon's path is always concave to the Sun in the center of the Earth's annual Orbit. Fig. II.

In this Diagram, the thickest curve line *ABCDE*, with the numeral figures set to it, represents as much of the Earth's annual Orbit as it describes in 32 days from west to east; the little circles at *a*, *b*, *c*, *d*, *e* shew the Moon's Orbit in due propor-

 tion

PLATE VII. tion to the Earth's; and the smallest curve *a b c d e f* represents the line of the Moon's path in the Heavens for 32 days, accounted from any particular New Moon at *a*. The Machine, Fig. 5th, is for delineating the Moon's path, and will be described, with the rest of my Astronomical machinery, in the last Chapter. The Sun is supposed to be in the center of the curve *A* 1 2 3 4 5 6 7 *B* &c. and the small dotted circles upon it represent the Moon's Orbit, of which the radius is in the same proportion to the Earth's path in this scheme, that the radius of the Moon's Orbit in the Heavens bears to the radius of the Earth's annual path round the Sun; that is, as 240,000 to 81,000,000, or as 1 to $337\frac{1}{2}$.

Proportion of the Moon's Orbit to the Earth's.

Fig. II. When the Earth is at *A*, the New Moon is at *a*; and in the seven days that the Earth describes the curve 1 2 3 4 5 6 7, the Moon in accompanying the Earth describes the curve *a b*; and is in her first Quarter at *b* when the Earth is at *B*. As the Earth describes the curve *B* 8 9 10 11 12 13 14, the Moon describes the curve *b c*; and is at *c*, opposite to the Sun, when the Earth is at *C*. Whilst the Earth describes the curve *C* 15 16 17 18 19 20 21 22, the Moon describes the curve *c d*; and is in her third Quarter at *d* when the Earth is at *D*. Once more, whilst the Earth describes the curve *D* 23 24 25 26 27 28 29, the Moon describes the curve *d e*; and is again in conjuction at *e* with the Sun when the Earth is at *E*, between the 29th and 30th day of the Moon's age, accounted by the numeral Figures from the New Moon at *A*. In describing the curve *a b c d e*, the Moon goes round the progressive Earth as really as if she had kept in the dotted Circle *A*, and the Earth continued immoveable in the center of that Circle.

The Moon's motion always concave towards the Sun.

And thus we see, that although the Moon goes round the Earth in a Circle, with respect to the Earth's center, her real path in the Heavens is not very different in appearance from the Earth's path.

To

To ſhew that the Moon's path is concave to the Sun, even at the time of Change, it is carried on a little farther into a ſecond Lunation, as to *f*.

267. The Moon's abſolute motion from her Change to her firſt Quarter, or from *a* to *b*, is ſo much ſlower than the Earth's, that ſhe falls 240 thouſand miles (equal to the ſemidiameter of her Orbit) behind the Earth at her firſt Quarter in *b*, when the Earth is in *B*; that is, ſhe falls back a ſpace equal to her diſtance from the Earth. From that time her motion is gradually accelerated to her Oppoſition or Full at *c*, and then ſhe is come up as far as the Earth, having regained what ſhe loſt in her firſt Quarter from *a* to *b*. From the Full to the laſt Quarter at *d* her motion continues accelerated, ſo as to be juſt as far before the Earth at *D*, as ſhe was behind it at her firſt Quarter in *b*. But, from *d* to *e* her motion is retarded ſo, that ſhe loſes as much with reſpect to the Earth as is equal to her diſtance from it, or to the ſemidiameter of her Orbit; and by that means ſhe comes to *e*, and is then in conjunction with the Sun as ſeen from the Earth at *E*. Hence we find, that the Moon's abſolute motion is ſlower than the Earth's from her third Quarter to her firſt; and ſwifter than the Earth's from her firſt Quarter to her third: her path being leſs curved than the Earth's in the former caſe, and more in the latter. Yet it is ſtill bent the ſame way towards the Sun; for if we imagine the concavity of the Earth's Orbit to be meaſured by the length of a perpendicular line *C g*, let down from the Earth's place upon the ſtraight line *b g d* at the Full of the Moon, and connecting the places of the Earth at the end of the Moon's firſt and third Quarters, that length will be about 640 thouſand miles; and the Moon when New only approaching nearer to the Sun by 240 thouſand miles than the Earth is, the length of the perpendicular let down from her place at that time upon the ſame ſtraight line, and

How her motion is alternately retarded and accelerated.

 which

which ſhews the concavity of that part of her path, will be about 400 thouſand miles.

A difficulty removed.

268. The Moon's path being concave to the Sun throughout, demonſtrates that her gravity towards the Sun, at her Conjunction, exceeds her gravity towards the Earth. And if we conſider that the quantity of matter in the Sun is almoſt 230 thouſand times as great as the quantity of matter in the Earth, and that the attraction of each body diminiſhes as the ſquare of the diſtance from it increaſes, we ſhall ſoon find, that the point of equal attraction between the Earth and the Sun, is about 70 thouſand miles nearer the Earth than the Moon is at her Change. It may now appear ſurpriſing that the Moon does not abandon the Earth when ſhe is between it and the Sun, becauſe ſhe is conſiderably more attracted by the Sun than by the Earth at that time. But this difficulty vaniſhes when we conſider, that a common impulſe on any ſyſtem of bodies affects not their relative motions; but that they will continue to attract, impel, or circulate round one another, in the ſame manner as if there was no ſuch impulſe. The Moon is ſo near the Earth, and both of them ſo far from the Sun, that the attractive power of the Sun may be conſidered as equal on both: and therefore the Moon will continue to circulate round the Earth in the ſame manner as if the Sun did not attract them at all: like bodies in the cabbin of a ſhip, which move round or impel one another in the ſame manner when the ſhip is under ſail, as when it is at reſt; becauſe they are all equally affected by the common motion of the ſhip. If by any other cauſe, ſuch as the near approach of a Comet, the Moon's diſtance from the Earth ſhould happen to be ſo much increaſed, that the difference of their gravitating forces towards the Sun ſhould exceed that of the Moon towards the Earth; in that caſe, the Moon, when in conjunc-

tion, would abandon the Earth, and be either drawn into the Sun, or Comet, or circulate round about it. PLATE VII.

269. The curves which Jupiter's Satellites defcribe, are all of different forts from the path defcribed by our Moon, although thefe Satellites go round Jupiter, as the Moon goes round the Earth. Let *A B C D E* &c. be as much of Jupiter's Orbit as he defcribes in 18 days from *A* to *T*; and the curves *a*, *b*, *c*, *d* will be the paths of his four Moons going round him in his progreffive motion. Fig. III.

Now let us fuppofe all thefe Moons to fet out from a conjunction with the Sun, as feen from Jupiter at *A*; then, his firft or neareft Moon will be at *a*, his fecond at *b*, his third at *c*, and his fourth at *d*. At the end of 24 terreftrial hours after this conjunction, Jupiter has moved to *B*, his firft Moon or Satellite has defcribed the curve *a* 1, his fecond the curve *b* 1, his third *c* 1, and his fourth *d* 1. The next day, when Jupiter is at *C*, his firft Satellite has defcribed the curve *a* 2, from its conjunction, his fecond the curve *b* 2, his third the curve *c* 2, and his fourth the curve *d* 2, and fo on. The numeral Figures under the capital letters fhew Jupiter's place in his path every day for 18 days, accounted from *A* to *T*; and the like Figures fet to the paths of his Satellites, fhew where they are at the like times. The firft Satellite, almoft under *C*, is ftationary at + as feen from the Sun; and retrograde from + to 2: at 2 it appears ftationary again, and thence it moves forward until it has paft 3, and is twice ftationary, and once retrograde, between 3 and 4. The path of this Satellite interfects itfelf every 42½ hours, making fuch loops as in the Diagram at 2. 3. 5. 7. 9. 10. 12. 14. 16. 18, a little after every Conjunction. The fecond Satellite *b*, moving flower, barely croffes it's path every 3 days 13 hours; as at 4. 7. 11. 14. 18, making

The abfolute Path of Jupiter and his Satellites delineated.

PLATE VII. making only five loops and as many conjunctions in the time that the first makes ten. The third Satellite *c* moving still slower, and having described the curve *c* 1. 2. 3. 4. 5. 6. 7, comes to an angle at 7 in conjunction with the Sun at the end of 7 days four hours; and so goes on to describe such another curve 7. 8. 9. 10. 11. 12. 13. 14, and is at 14 in it's next conjunction. The fourth Satellite *d* is always progressive, making neither loops nor angles in the Heavens; but comes to it's next conjunction at *e* between the numeral figures 16 and 17, or in 16 days 18 hours. In order to have a tolerably good figure of the paths of these Satellites, I took the following method.

Fig. III.

Fig. IV.

How to delineate the paths of Jupiter's Moon.

Having drawn their Orbits on a Card, in proportion to their relative distances from Jupiter, I measured the radius of the Orbit of the fourth Satellite, which was an inch and $\frac{14}{100}$ parts of an inch; then multiplied this by 424 for the radius of Jupiter's Orbit, because Jupiter is 424 times as far from the Sun's center as his fourth Satellite is from his center; and the product thence arising was $483\frac{16}{100}$ inches. Then taking a small cord of this length, and fixing one end of it to the floor of a long room by a nail, with a black-lead pencil at the other end I drew the curve *ABCD* &c. and set off a degree and a half thereon, from *A* to *T*; because Jupiter moves only so much, whilst his outermost Satellite goes once round him, and somewhat more; so that this small portion of so large a circle differs but very little from a straight line. This done, I divided the space *AT* into 18 equal parts, as *AB*, *BC*, &c. for the daily progress of Jupiter; and each part into 24 for his hourly progress. The Orbit of each Satellite was also divided into as many equal parts as the Satellite is hours in finishing it's synodical period round Jupiter. Then drawing a right line through the center of the Card, as a diameter to all the four Orbits upon it, I put the card upon the line of Jupiter's

Jupiter's motion, and transferred it to every horary divifion thereon, keeping always the faid diameter-line on the line of Jupiter's path; and running a pin through each horary divifion in the Orbit of each Satellite as the card was gradually transferred along the line *ABCD* &c. of Jupiter's motion, I marked points for every hour through the Card for the Curves defcribed by the Satellites, as the primary Planet in the center of the Card was carried forward on the line: and fo finifhed the Figure, by drawing the lines of each Satellite's motion through thofe (almoft innumerable) points: by which means, this is perhaps as true a Figure of the paths of thefe Satellites as can be defired. And in the fame manner might thofe for Saturn's Satellites be delineated. PLATE VII. And Saturn's.

270. It appears by the fcheme, that the three firft Satellites come almoft into the fame line or pofition every feventh day; the firft being only a little behind with the fecond, and the fecond behind with the third. But the period of the fourth Satellite is fo incommenfurate to the periods of the other three, that it cannot be gueffed at by the diagram when it would fall again into a line of conjunction with them, between Jupiter and the Sun. And no wonder; for fuppofing them all to have been once in conjunction, it will require 3,087,043,493,260 years to bring them in conjunction again. See § 73. The grand Period of Jupiter's Moons.

271. In Fig. 4th we have the proportions of the Orbits of Saturn's five Satellites, and of Jupiter's four, to one another, to our Moon's Orbit, and to the Difc of the Sun. *S* is the Sun; *M m* the Moon's Orbit (the Earth fuppofed to be at *E*;) *J* Jupiter; 1. 2. 3. 4 the Orbits of his four Moons or Satellites; *Sat* Saturn; and 1. 2. 3. 4. 5 the Orbits of his five Moons. Hence it appears, that the Sun would much more than fill the whole Orbit of the Moon; for the Sun's diameter is 763,000 miles, and the diameter of the Moon's Orbit Fig. IV. The proportions of the Orbits of the Planets and Satellites.

Orbit only 480,000. In proportion to all these Orbits of the Satellites, the radius of Saturn's annual Orbit would be 21$\frac{1}{4}$ yards, of Jupiter's Orbit 11$\frac{2}{3}$, and of the Earth's 2$\frac{1}{4}$, taking them in round numbers.

272. The annexed table shews at once what proportion the Orbits, Revolutions, and Velocities, of all the Satellites bear to those of their primary Planets, and what sort of curves the several Satellites describe. For, those Satellites whose velocities round their Primaries are greater than the velocities of their Primaries in open space, make loops at their conjunctions, § 269; appearing retrograde as seen from the Sun whilst they describe the inferior parts of their Orbits, and direct whilst they describe the superior. This is the case with Jupiter's first and second Satellites, and with Saturn's first. But those Satellites, whose velocities are less than the velocities of their primary Planets, move direct in their whole circumvolutions; which is the case of the third and fourth Satellites of Jupiter, and of the second, third, fourth, and fifth Satellites of Saturn, as well as of our Satellite the Moon: But the Moon is the only Satellite whose motion is always concave to the Sun. There is a

The Satellites		Proportion of the Radius of the Planet's Orbit to the Radius of the Orbit of each Satellite.	Proportion of the Time of the Planet's Revolution to the Revolution of each Satellite.	Proportion of the Velocity of each Satellite to the Velocity of it's primary Planet.
of Saturn	1	As 5322 to 1	As 5738 to 1	As 5738 to 5322
	2	4155 1	3912 1	3912 4155
	3	2954 1	2347 1	2347 2954
	4	1295 1	674 1	674 1295
	5	432 1	134 1	134 432
of Jupiter	1	As 1851 to 1	As 2445 to 1	As 2445 to 1851
	2	1165 1	1219 1	1219 1165
	3	731 1	604 1	604 731
	4	424 1	258 1	258 424
The Moon		As 337$\frac{1}{2}$ to 1	As 12$\frac{1}{3}$ to 1	As 12$\frac{1}{3}$ to 337$\frac{1}{2}$

table

table of this sort in *De la Caille*'s Astronomy, but it is very different from the above, which I have computed from our *English* accounts of the periods and distances of these Planets and Satellites.

CHAP. XVI.

The Phenomena of the Harvest-Moon explained by a common Globe: The years in which the Harvest-Moons are least and most beneficial from 1751, *to* 1861. *The long duration of Moon-light at the Poles in winter.*

273. IT is generally believed that the Moon rises about 50 minutes later every day than on the preceding; but this is true only with regard to places on the Equator. In places of considerable Latitude there is a remarkable difference, especially in the harvest time; with which Farmers were better acquainted than Astronomers till of late; and gratefully ascribed the early rising of the Full Moon at that time of the year to the goodness of God, not doubting that he had ordered it so on purpose to give them an immediate supply of Moon-light after sun-set for their greater conveniency in reaping the fruits of the Earth.

No Harvest-Moon at the Equator.

In this instance of the Harvest-Moon, as in many others discoverable by Astronomy, the wisdom and beneficence of the Deity is conspicuous, who really ordered the course of the Moon so, as to bestow more or less light on all parts of the Earth as their several circumstances and seasons render it more or less serviceable. About the Equator, where there is no variety of seasons, and the weather changes seldom, and at stated times, Moon-light is not necessary for gathering in the produce of the ground; and there the Moon rises about 50 minutes later every day or night than on the former. At considerable distances from the Equator, where the weather and seasons are more uncertain, the autumnal Full Moons rise very soon after sun-set for several evenings together. At the polar circles, where the mild season is of very short duration, the autumnal Full Moon rises at sun-set from the first to the third quarter. And at the Poles, where the Sun is for half a year absent, the winter Full Moons shine constantly without setting from the first to the third quarter.

But remarkable according to the distance of places from it.

The reason of this.

It is soon said that all these Phenomena are owing to the different Angles made by the Horizon and different parts of the Moon's Orbit; and that the Moon can be full but once or twice in a year in those parts of her Orbit which rise with the least angles. But to explain this subject intelligibly, we must dwell much longer upon it.

274. The * plane of the Equinoctial is perpendicular to the Earth's Axis: and therefore, as the Earth turns round it's Axis, all parts of the Equinoctial make equal Angles with the Horizon both at rising and setting; so that equal portions of it always rise or set in equal times. Consequently, if the Moon's motion were equable, and in the Equinoctial, at the rate of 12 degrees 11 min. from the Sun every day, as it is in her Orbit, she would rise and set 50 minutes later every day than on the preceding: for 12 deg. 11 min. of the Equinoctial rise or set in 50 minutes of time in all Latitudes.

275. But the Moon's motion is so nearly in the Ecliptic, that we may consider her at present as moving in it. Now the different parts of the Ecliptic, on account of it's obliquity to the Earth's Axis, make very different Angles with the Horizon as they rise or set. Those parts or Signs which rise with the smallest Angles set with the greatest, and *vice versâ.* In equal times, whenever this Angle is least, a greater portion of the Ecliptic rises than when the Angle is larger; as may be seen by elevating the pole of a Globe to any con-

* If a Globe be cut quite through upon any Circle, the flat surface where it is so divided, is the plane of that Circle.

siderable

ſiderable Latitude, and then turning it round it's Axis in the Horizon. Conſequently, when the Moon is in thoſe Signs which riſe or ſet with the ſmalleſt Angles, ſhe riſes or ſets with the leaſt difference of time; and with the greateſt difference in thoſe Signs which riſe or ſet with the greateſt Angles. PLATE III.

Fig. III.

But, becauſe all who read this Treatiſe may not be provided with Globes, though in this caſe it is requiſite to know how to uſe them, we ſhall ſubſtitute the Figure of a globe; in which *FUP* is the Axis, ♋ *TR* the Tropic of Cancer, *Lt* ♑ the Tropic of Capricorn, ♋ *EU* ♑ the Ecliptic touching both the Tropics, which are 47 degrees from each other, and *AB* the Horizon. The Equator, being in the middle between the Tropics, is cut by the Ecliptic in two oppoſite points, which are the beginnings of ♈ Aries and ♎ Libra, *K* is the Hour-circle with its Index, *F* the North Pole of the Globe elevated to a conſiderable Latitude, ſuppoſe 40 degrees above the Horizon; and *P* the South Pole depreſſed as much below it. Fig. III. Becauſe of the oblique poſition of the Sphere in this Latitude, the Ecliptic has the high elevation *N* ♋ above the Horizon, making the Angle *NU* ♋ of $73\frac{1}{2}$ degrees with it when ♋ Cancer is on the Meridian, at which time ♎ Libra riſes in the Eaſt. But let the Globe be turned half round it's Axis, till ♑ Capricorn comes to the Meridian and ♈ Aries riſes in the Eaſt, and then the Ecliptic will have the low elevation *NL* above the Horizon, making only an Angle *NUL* of $26\frac{1}{2}$ degrees with it; which is 47 degrees leſs than the former Angle, equal to the diſtance between the Tropics.

The different Angles made by the Ecliptic and Horizon.

276. In northern Latitudes, the ſmalleſt Angle made by the Ecliptic and Horizon is when Aries riſes, at which time Libra ſets: the greateſt when Libra riſes, at which time Aries ſets. From the riſing of Aries to the riſing of Libra (which is twelve

Leaſt and greateſt, when.

twelve * Sydereal hours) the angle increases; and from the rising of Libra to the rising of Aries it decreases in the same proportion. By this article and the preceding, it appears that the Ecliptic rises fastest about Aries, and slowest about Libra.

Result of the quantity of this Angle at London.

277. On the Parallel of *London*, as much of the Ecliptic rises about Pisces and Aries in two hours as the Moon goes through in six days: and therefore whilst the Moon is in these Signs, she differs but two hours in rising for six days together; that is, about 20 minutes later every day or night than on the preceding, at a mean rate. But in fourteen days afterwards, the Moon comes to Virgo and Libra, which are the opposite Signs to Pisces and Aries; and then she differs almost four times as much in rising; namely, one hour and about fifteen minutes later every day or night than the former, whilst she is in these Signs. The annexed Table shews the daily mean difference of the Moon's

Days	Signs	Degrees	Rising Diff.		Setting Diff.	
			H.	M.	H.	M.
1	♋	13	1	5	0	50
2		26	1	10	0	43
3	♌	10	1	14	0	37
4		23	1	17	0	32
5	♍	6	1	16	0	28
6		19	1	15	0	24
7	♎	2	1	15	0	20
8		15	1	15	0	18
9		28	1	15	0	17
10	♏	12	1	15	0	22
11		25	1	14	0	30
12	♐	8	1	13	0	39
13		21	1	10	0	47
14	♑	4	1	4	0	56
15		17	0	46	1	5
16	♒	1	0	40	1	8
17		14	0	35	1	12
18		27	0	30	1	15
19	♓	10	0	25	1	16
20		23	0	20	1	17
21	♈	7	0	17	1	16
22		20	0	17	1	15
23	♉	3	0	20	1	15
24		16	0	24	1	15
25		29	0	30	1	14
26	♊	13	0	40	1	13
27		26	0	56	1	7
28	♋	9	1	0	1	58

* The Ecliptic, together with the fixed Stars, make 366¼ apparent diurnal revolutions about the Earth in a year; the Sun only 365¼. Therefore the Stars gain 3 minutes 56 seconds upon the Sun every day: so that a Sydereal day contains only 23 hours 56 minutes of mean Solar time; and a natural or Solar day 24 hours. Hence 12 Sydereal hours are 1 minute 58 seconds shorter than 12 Solar.

rising

ward, and in that time, ſuppoſe the patch o to have moved thence to 1, $13\frac{1}{6}$ degrees, whilſt the Earth turns once round it's Axis, and you will ſee that 1 riſes only about 20 minutes later than o did on the day before. Turn the Globe round again, and in that time ſuppoſe the ſame patch to have moved from 1 to 2; and it will riſe only 20 minutes later by the hour-index than it did at 1 on the day or turn before. At the end of the next turn, ſuppoſe the patch to have gone from 2 to 3 at *U*, and it will riſe 20 minutes later than it did at 2. And ſo on for ſix turns, in which time there will ſcarce be two hours difference: nor would there have been ſo much if the 6 degrees of the Sun's motion in that time had been allowed for. At the firſt Turn the patch riſes ſouth of the Eaſt, at the middle Turn due Eaſt, and at the laſt Turn north of the Eaſt. But theſe patches will be 9 hours of ſetting on the weſtern ſide of the Horizon, which ſhews that the Moon will be ſo much later of ſetting in that week in which ſhe moves through theſe two Signs. The cauſe of this difference is evident; for Piſces and Aries make only an Angle of 15 degrees with the Horizon when they riſe; but they make an Angle of 62 degrees with it when they ſet. As the Signs Taurus, Gemini, Cancer, Leo, Virgo, and Libra, riſe ſucceſſively, the Angle increaſes gradually which they make with the Horizon; and decreaſes in the ſame proportion as they ſet. And for that reaſon, the Moon differs gradually more in the time of her riſing every day whilſt ſhe is in theſe Signs, and leſs in her ſetting: after which, through the other ſix Signs, *viz.* Scorpio, Sagittary, Capricorn, Aquarius, Piſces, and Aries, the riſing difference becomes leſs every day, until it be at the leaſt of all, namely, in Piſces and Aries.

280. The Moon goes round the Ecliptic in 27 days 8 hours; but not from Change to Change in leſs than 29 days 12 hours: ſo that ſhe is in Piſces

and Aries at leaſt once in every Lunation, and in ſome Lunations twice.

281. If the Earth had no annual motion, the Sun would never appear to ſhift his place in the Ecliptic. And then every New Moon would fall in the ſame ſign and degree of the Ecliptic, and every Full Moon in the oppoſite: for the Moon would go preciſely round the Ecliptic from Change to Change. So that if the Moon was once Full in Piſces, or Aries, ſhe would always be Full when ſhe came round to the ſame Sign and Degree again. And as the Full Moon riſes at Sun-ſet (becauſe when any point of the Ecliptic ſets, the oppoſite point riſes) ſhe would conſtantly riſe within two hours of Sun-ſet, on the parallel of *London*, during the week in which ſhe were Full. But in the time that the Moon goes round the Ecliptic from any conjunction or oppoſition, the Earth goes almoſt a Sign forward; and therefore the Sun will ſeem to go as far forward in that time, namely, $27\frac{1}{2}$ degrees; ſo that the Moon muſt go $27\frac{1}{2}$ degrees more than round, and as much farther as the Sun advances in that interval, which is $2\frac{1}{17}$ degrees, before ſhe can be in conjunction with, or oppoſite to, the Sun again. Hence it is evident, that there can be but one conjunction or oppoſition of the Sun and Moon in a year in any particular part of the Ecliptic. This may be familiarly exemplified by the hour and minute hands of a watch, which are never in conjunction or oppoſition in that part of the dial-plate where they were ſo laſt before. And indeed if we compare the twelve hours on the dial-plate to the twelve ſigns of the Ecliptic, the hour-hand to the Sun and the minute-hand to the Moon, we ſhall have a tolerably near reſemblance in miniature to the motions of our great celeſtial Luminaries. The only difference is, that whilſt the Sun goes once round the Ecliptic, the Moon makes $12\frac{1}{7}$ conjunctions with him: but whilſt the hour-hand goes round the dial-

Why the Moon is always Full in different Signs.

Her periodical and ſynodical Revolution exemplified.

dial-plate, the minute-hand makes only 11 conjunctions with it; because the minute-hand moves slower in respect of the Hour-hand than the Moon does with regard to the Sun.

The Harvest and Hunter's Moon. 282. As the Moon can never be full but when she is opposite to the Sun, and the Sun is never in Virgo and Libra but in our autumnal months, it is plain that the Moon is never full in the opposite Signs, Pisces and Aries, but in these two months. And therefore we can have only two Full Moons in the year, which rise so near the time of Sun-set for a week together, as above-mentioned. The former of these is called the *Harvest Moon*, and the latter the *Hunter's Moon*.

Why the Moon's regular rising is never perceived but in Harvest. 283. Here it will probably be asked, why we never observe this remarkable rising of the Moon but in harvest, since she is in Pisces and Aries twelve times in the year besides; and must then rise with as little difference of time as in harvest? The answer is plain: for in winter these Signs rise at noon; and being then only a Quarter of a Circle distant from the Sun, the Moon in them is in her first Quarter: but when the Sun is above the Horizon, the Moon's rising is neither regarded nor perceived. In spring these Signs rise with the Sun, because he is then in them; and as the Moon changeth in them at that time of the year, she is quite invisible. In summer they rise about midnight, and the Sun being then three Signs, or a Quarter of a Circle before them, the Moon is in them about her third Quarter; when rising so late, and giving but very little light, her rising passes unobserved. And in autumn, these Signs being opposite to the Sun, rise when he sets, with the Moon in opposition, or at the Full, which makes her rising very conspicuous.

284. At the Equator, the North and South Poles lie in the Horizon; and therefore the Ecliptic makes the same Angle southward with the Horizon

rizon when Aries rises, as it does northward when Libra rises. Consequently, as the Moon at all the fore-mentioned patches rises and sets nearly at equal Angles with the Horizon all the year round, and about 50 minutes later every day or night than on the preceding, there can be no particular Harvest-Moon at the Equator.

285. The farther that any place is from the Equator, if it be not beyond the Polar Circle, the Angle gradually diminishes which the Ecliptic and Horizon make when Pisces and Aries rise: and therefore when the Moon is in these Signs she rises with a nearly proportionable difference later every day than on the former; and is for that reason the more remarkable about the Full, until we come to the Polar Circles, or 66 degrees from the Equator; in which Latitude the Ecliptic and Horizon become coincident every day for a moment, at the same sydereal hour (or 3 minutes 56 seconds sooner every day than the former) and the very next moment one half of the Ecliptic containing Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini, rises, and the opposite half sets. Therefore, whilst the Moon is going from the beginning of Capricorn to the beginning of Cancer, which is almost 14 days, she rises at the same sydereal hour; and in autumn just at Sun-set, because all that half of the Ecliptic, in which the Sun is at that time, sets at the same sydereal hour, and the opposite half rises; that is, 3 minutes 56 seconds, of mean solar time, sooner every day than on the day before. So whilst the Moon is going from Capricorn to Cancer, she rises earlier every day than on the preceding; contrary to what she does at all places between the polar Circles. But during the above fourteen days, the Moon is 24 sydereal hours later in setting; for the six Signs which rise all at once on the eastern side of the Horizon are 24 hours in setting on the western side of it; as any one may see by making chalk-marks

at the beginning of Capricorn and of Cancer, and then, having elevated the Pole 66½ degrees, turn the Globe ſlowly round it's Axis, and obſerve the riſing and ſetting of the Ecliptic. As the beginning of Aries is equally diſtant from the beginning of Cancer and of Capricorn, it is in the middle of that half of the Ecliptic which riſes all at once. And when the Sun is at the beginning of Libra, he is in the middle of the other half. Therefore, when the Sun is in Libra, and the Moon in Capricorn, the Moon is a Quarter of a Circle before the Sun; oppoſite to him, and conſequently full in Aries, and a Quarter of a Circle behind him, when in Cancer. But when Libra riſes, Aries ſets, and all that half of the Ecliptic of which Aries is the middle, and therefore, at that time of the year, the Moon riſes at Sun-ſet from her firſt to her third Quarter.

The Harveſt-Moons regular on both ſides of the Equator.

286. In northern Latitudes, the autumnal Full Moons are in Piſces and Aries; and the vernal Full Moons in Virgo and Libra: in ſouthern Latitudes juſt the reverſe, becauſe the ſeaſons are contrary. But Virgo and Libra riſe at as ſmall Angles with the Horizon in ſouthern Latitudes, as Piſces and Aries do in the northern; and therefore the Harveſt-Moons are juſt as regular on one ſide of the Equator as on the other.

287. As theſe Signs, which riſe with the leaſt Angles, ſet with the greateſt, the vernal Full Moons differ as much in their times of riſing every night as the autumnal Full Moons differ in their times of ſetting; and ſet with as little difference as the autumnal Full Moons riſe: the one being in all caſes the reverſe of the other.

288. Hitherto, for the ſake of plainneſs, we have ſuppoſed the Moon to move in the Ecliptic, from which the Sun never deviates. But the Orbit in which the Moon really moves is different from the Ecliptic: one half being elevated 5⅓ degrees above it, and the other half as much depreſſed

pressed below it. The Moon's Orbit therefore intersects the Ecliptic in two points diametrically opposite to each other; and these intersections are called the *Moon's Nodes.* So the Moon can never be in the Ecliptic but when she is in either of her Nodes, which is at least twice in every course from Change to Change, and sometimes thrice. For, as the Moon goes almost a whole Sign more than round her Orbit from Change to Change; if she passes by either Node about the time of Change, she will pass by the other in about fourteen days after, and come round to the former Node two days again before the next Change. That Node from which the Moon begins to ascend northward, or above the Ecliptic, in northern Latitudes, is called the *Ascending Node*; and the other the *Descending Node*, because the Moon, when she passes by it, descends below the Ecliptic southward.

The Moon's Nodes.

289. The Moon's oblique motion with regard to the Ecliptic causes some difference in the times of her rising and setting from what is already mentioned. For whilst she is northward of the Ecliptic, she rises sooner and sets later than if she moved in the Ecliptic: and when she is southward of the Ecliptic, she rises later and sets sooner. This difference is variable, even in the same Signs, because the Nodes shift backward about $19\frac{1}{3}$ degrees in the Ecliptic every year; and so go round it contrary to the order of Signs in 18 years 225 days.

290. When the Ascending Node is in Aries, the southern half of the Moon's Orbit makes an Angle of $5\frac{1}{3}$ degrees less with the Horizon than the Ecliptic does, when Aries rises in northern Latitudes: for which reason the Moon rises with less difference of time whilst she is in Pisces and Aries, than there would be if she kept in the Ecliptic. But in 9 years and 112 days afterward, the Descending Node comes to Aries; and then the Moon's Orbit makes an Angle $5\frac{1}{3}$ degrees greater with the Horizon when Aries rises, than the

Ecliptic does at that time; which causes the Moon to rise with greater difference of time in Pisces and Aries than if she moved in the Ecliptic.

291. To be a little more particular; when the Ascending Node is in Aries, the Angle is only $9\frac{2}{3}$ degrees on the parallel of *London* when Aries rises. But when the Descending Node comes to Aries, the Angle is $20\frac{1}{3}$ degrees; this occasions as great a difference of the Moon's rising in the same Signs every 9 years, as there would be on two parallels to $10\frac{2}{3}$ degrees from one another, if the Moon's course were in the Ecliptic. The following Table shews how much the obliquity of the Moon's Orbit affects her rising and setting on the parallel of *London*, from the 12th to the 18th day of her age; supposing her to be Full at the autumnal Equinox: and then, either in the Ascending Node, highest part of her Orbit, Descending Node, or lowest part of her Orbit. *M* signifies morning, *A* afternoon; and the line at the foot of the Table shews a week's difference in rising and setting.

Moon's Age.	Full in her Ascending node.		In the highest part of her Orbit.		Full in her Descending node.		In the lowest part of her Orbit.	
	Rises at H. M.	Sets at H. M.	Rises at H. M.	Sets at H. M.	Rises at H. M.	Sets at H. M.	Rises at H. M.	Sets at H. M.
12	5 *A* 15	3 *M* 20	4 *A* 30	3 *M* 15	4 *A* 32	3 *M* 40	5 *A* 16	3 *M* 0
13	5 32	4 25	4 50	4 45	5 15	4 20	6 0	4 15
14	5 48	5 30	5 16	6 0	5 45	5 40	6 20	5 28
15	6 5	7 0	5 42	7 20	6 15	6 56	6 45	6 32
16	6 20	8 15	6 2	8 35	6 46	8 0	7 8	7 45
17	6 36	9 12	6 26	9 45	7 18	9 15	7 30	9 15
18	6 54	10 30	7 0	10 40	8 0	10 20	7 52	10 0
Dif.	1 39	7 10	2 30	7 25	3 28	6 40	2 36	7 0

This Table was not computed, but only estimated as near as could be done from a common Globe, on which the Moon's Orbit was delineated with a black-lead pencil. It may at first sight appear

pear erroneous; since as we have supposed the Moon to be full in either Node at the autumnal Equinox, she ought by the Table to rise just at six o'clock or at Sun-set, on the 15th day of her age; being in the Ecliptic at that time. But it must be considered, that the Moon is only $14\frac{3}{4}$ days old when she is Full; and therefore in both cases she is a little past the Node on the 15th day, being above it at one time, and below it at the other.

292. As there is a compleat revolution of the Nodes in $18\frac{2}{3}$ years, there must be a regular period of all the Varieties which can happen in the rising and setting of the Moon during that time. But this shifting of the Nodes never affects the Moon's rising so much, even in her quickest descending Latitude, as not to allow us still the benefit of her rising nearer the time of Sun-set for a few days together about the Full in Harvest, than when she is Full at any other time of the year. The following Table shews in what years the Harvest-Moons are least beneficial as to the times of their rising, and in what years most, from 1751 to 1861. The column of years under the letter *L* are those in which the Harvest-Moons are least of all beneficial, because they fall about the Descending Node: and those under *M* are the most of all beneficial, because they fall about the Ascending Node. In all the columns from *N* to *S* the Harvest-Moons descend gradually in the Lunar Orbit, and rise to less heights above the Horizon. From *S* to *N* they ascend in the same proportion, and rise to greater heights above the Horizon. In both the columns under *S* the Harvest-Moons are in the lowest part of the Moon's Orbit, that is, farthest South of the Ecliptic; and therefore stay shortest of all above the Horizon: in the columns under *N* just the reverse. And in both cases, their rising, though not at the same times, are nearly the same with regard to difference of time, as if the Moon's Orbit were coincident with the Ecliptic.

The period of the Harvest-Moon.

Years

Years in which the Harveſt-Moons are leaſt beneficial.									
N					L			S	
1751	1752	1753	1754	1755	1756	1757	1758	1759	
1770	1771	1772	1773	1774	1775	1776	1777	1778	
1788	1789	1790	1791	1792	1793	1794	1795	1796	1797
1807	1808	1809	1810	1811	1812	1813	1814	1815	
1826	1827	1828	1829	1830	1831	1832	1833	1834	
1844	1845	1846	1847	1848	1849	1850	1851	1852	
Years in which they are moſt beneficial.									
S					M			N	
1760	1761	1762	1763	1764	1765	1766	1767	1768	1769
1779	1780	1781	1782	1783	1784	1785	1786	1787	
1798	1799	1800	1801	1802	1803	1804	1805	1806	
1816	1817	1818	1819	1820	1821	1822	1823	1824	1825
1835	1836	1837	1838	1839	1840	1841	1842	1843	
1853	1854	1855	1856	1857	1858	1859	1860	1861	

293. At the Polar Circles, when the Sun touches the Summer Tropic, he continues 24 hours above the Horizon; and 24 hours below it when he touches the Winter Tropic. For the ſame reaſon the Full Moon neither riſes in Summer, nor ſets in Winter, conſidering her as moving in the Ecliptic. For the Winter Full Moon being as high in the Ecliptic as the Summer Sun, muſt therefore continue as long above the Horizon; and the Summer Full Moon being as low in the Ecliptic as the Winter Sun, can no more riſe than he does. But theſe are only the two Full Moons which happen about the Tropics, for all the others riſe and ſet. In Summer the Full Moons are low, and their ſtay is ſhort above the Horizon, when the nights are ſhort, and we have leaſt occaſion for Moon-light: in Winter they go high, and ſtay long above the Horizon, when the nights are long, and we want the greateſt quantity of Moon-light.

The long continuance of Moon-light at the Poles.

294. At the Poles, one half of the Ecliptic never ſets, and the other half never riſes: and therefore, as the Sun is always half a year in deſcribing one half of the Ecliptic, and as long in going through the other half, it is natural to imagine

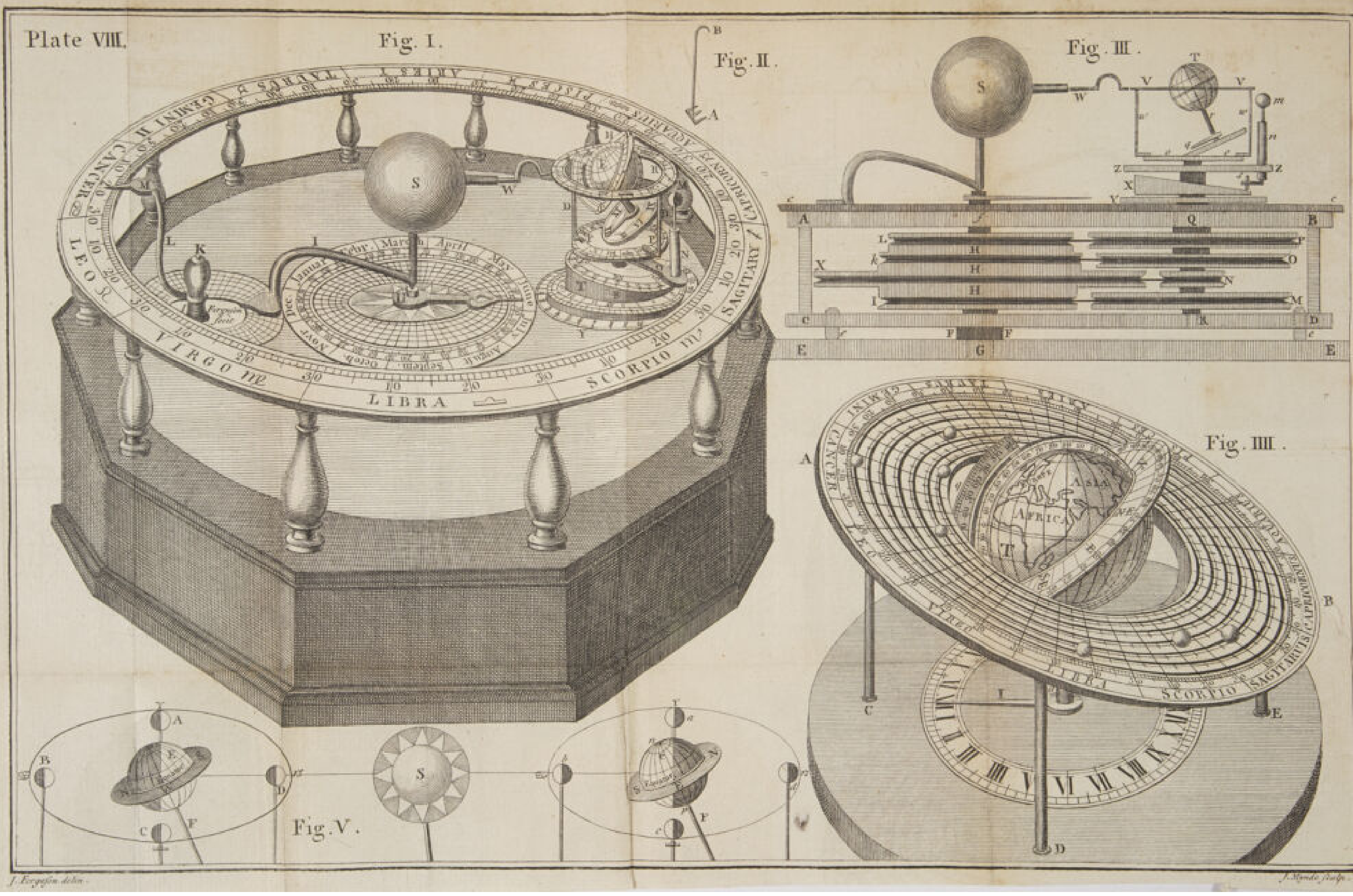
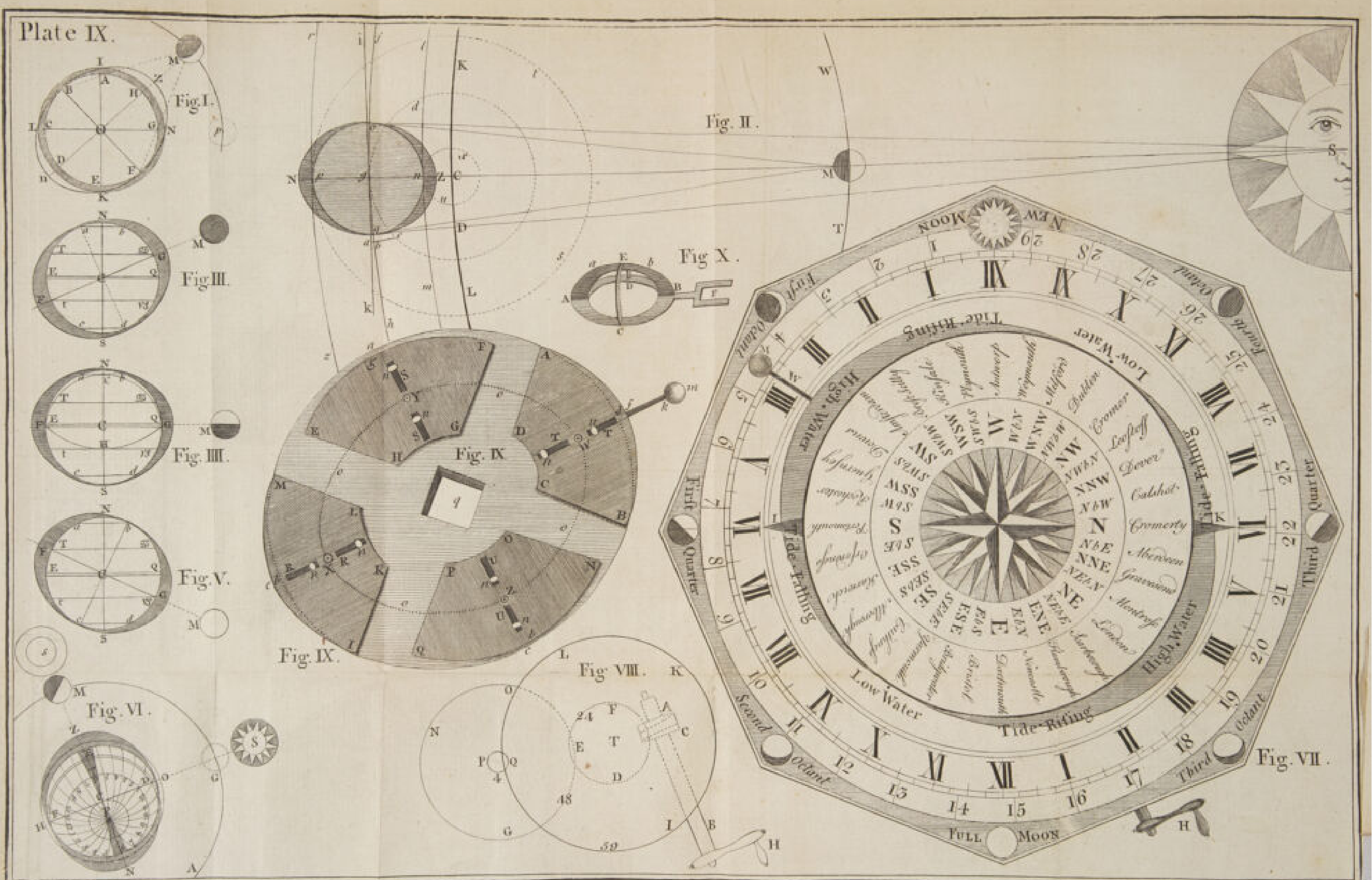


Plate VIII.
Fig. I.
Fig. II.
Fig. III.
Fig. IIII.
Fig. V.
LIBRA
SCORPIO
VIRGO
LEO
CANCER
GEMINI
TAURUS
ARIES
PISCES
AQUARIUS
CAPRICORN
SAGITTARY
ASIA
AFRICA
J. Ferguson delin.
J. Mynde sculp.

gine that the Sun continues half a year together above the Horizon of each Pole in it's turn, and as long below it; rising to one Pole when he sets to the other. This would be exactly the case if there were no refraction: but by the Atmosphere's refracting the Sun's rays, he becomes visible some days sooner, § 183, and continues some days longer in sight than he would otherwise do: so that he appears above the Horizon of either Pole before he has got below the Horizon of the other. And, as he never goes more than $23\frac{1}{2}$ degrees below the Horizon of the Poles, they have very little dark night: it being twilight there as well as at all other places till the Sun be 18 degrees below the Horizon, § 177. The Full Moon being always opposite to the Sun, can never be seen while the Sun is above the Horizon, except when the Moon falls in the northern half of her Orbit; for whenever any point of the Ecliptic rises, the opposite point sets. Therefore, as the Sun is above the Horizon of the north Pole from the 20th of *March* till the 23d of *September*, it is plain that the Moon, when Full, being opposite to the Sun, must be below the Horizon during that half of the year. But when the Sun is in the southern half of the Ecliptic, he never rises to the north Pole, during which half of the year, every Full Moon happens in some part of the northern half of the Ecliptic, which never sets. Consequently, as the polar Inhabitants never see the Full Moon in Summer, they have her always in the Winter, before, at, and after the Full, shining for 14 of our days and nights. And when the Sun is at his greatest depression below the Horizon, being then in Capricorn, the Moon is at her First Quarter in Aries, Full in Cancer, and at her Third Quarter in Libra. And as the beginning of Aries is the rising point of the Ecliptic, Cancer the highest, and Libra the setting point, the Moon rises at her first Quarter in Aries, is most elevated above the Horizon,

PLATE VIII. Horizon, and Full in Cancer, and ſets at the beginning of Libra in her Third Quarter, having continued viſible for 14 diurnal rotations of the Earth. Thus the Poles are ſupplied one half of the winter time with conſtant Moon-light in the Sun's abſence; and only loſe ſight of the Moon from her Third to her Firſt Quarter, while ſhe gives but very little light; and could be but of little, and ſometimes of no ſervice to them. A

Fig. V. bare view of the Figure will make this plain; in which let *S* be the Sun, *e* the Earth in Summer when it's north Pole *n* inclines toward the Sun, and *E* the Earth in Winter, when it's north Pole declines from him. *S E N* and *N W S* is the Horizon of the north Pole, which is coincident with the Equator; and, in both theſe poſitions of the Earth, ♈ ♋ ♎ ♑ is the Moon's Orbit, in which ſhe goes round the Earth, according to the order of the letters *a b c d*, *A B C D*. When the Moon is at *a*, ſhe is in her Third Quarter to the Earth at *e*, and juſt riſing to the north Pole *n*; at *b* ſhe changes, and is at the greateſt height above the Horizon, as the Sun likewiſe is; at *c* ſhe is in her Firſt Quarter, ſetting below the Horizon; and is loweſt of all under it at *d*, when oppoſite to the Sun, and her enlightened ſide toward the Earth. But then ſhe is full in view to the ſouth Pole *p*; which is as much turned from the Sun as the north Pole inclines towards him. Thus in our Summer, the Moon is above the Horizon of the north Pole whilſt ſhe deſcribes the northern half of the Ecliptic ♈ ♋ ♎, or from her Third Quarter to her Firſt; and below the Horizon during her progreſs through the ſouthern half ♎ ♑ ♈; higheſt at the Change, moſt depreſſed at the Full. But in Winter, when the Earth is at *E*, and it's north Pole declines from the Sun, the New Moon at *D* is at her greateſt depreſſion below the Horizon *N W S*, and the Full Moon at *B* at her greateſt height above it; riſing at her Firſt Quarter *A*, and



J. Ferguson delin.   J. Mynde sculp.

and keeping above the Horizon till ſhe comes to her Third Quarter *C*. At a mean ſtate ſhe is 23½ degrees above the Horizon at *B* and *b*, and as much below it at *D* and *d*, equal to the inclination of the Earth's Axis *F*. *S* ♋ and *S* ♑ are, as it were, a ray of light proceeding from the Sun to the Earth; and ſhews that when the Earth is at *e*, the Sun is above the Horizon, vertical to the Tropic of Cancer; and when the Earth is at *E*, he is below the Horizon, vertical to the Tropic of Capricorn.

CHAP. XVII.

Of the Ebbing and Flowing of the Sea.

295. THE cauſe of the Tides was diſcovered by KEPLER, who, in his *Introduction to the Phyſics of the Heavens*, thus explains it: "The Orb of the attracting power, which is in the Moon, is extended as far as the Earth; and draws the waters under the torrid Zone, acting upon places where it is vertical, inſenſibly on confined ſeas and bays, but ſenſibly on the ocean whoſe beds are large, and the waters have the liberty of reciprocation; that is, of riſing and falling." And in the 70th page of his *Lunar Aſtronomy*—— "But the cauſe of the Tides of the Sea appears to be the bodies of the Sun and Moon drawing the waters of the Sea." This hint being given, the immortal Sir ISAAC NEWTON improved it, and wrote ſo amply on the ſubject, as to make the Theory of the Tides in a manner quite his own; by diſcovering the cauſe of their riſing on the ſide of the Earth oppoſite to the Moon. For KEPLER believed, that the preſence of the Moon occaſioned an impulſe which cauſed another in her abſence.

The cauſe of the Tides diſcovered by KEPLER.

Their Theory improved by Sir ISAAC NEWTON.

296. It has been already ſhewn, § 106, that the power of gravity diminiſhes as the ſquare of the diſtance increaſes; and therefore the waters at *Z* on

Explained on the Newtonian principles.

PLATE IX. on the ſide of the Earth *ABCDEFGH* next the Moon *M* are more attracted than the central parts Fig. I. of the Earth *O* by the Moon, and the central parts are more attracted by her than the waters on the oppoſite ſide of the Earth at *n*: and therefore the diſtance between the Earth's center and the waters on it's ſurface under and oppoſite to the Moon will be increaſed. For, let there be three bodies at *H*, *O*, and *D*: if they are all equally attracted by the body *M*, they will all move equally faſt toward it, their mutual diſtances from each other continuing the ſame. If the attraction of *M* is unequal, then that body which is moſt ſtrongly attracted will move faſteſt, and this will increaſe it's diſtance from the other body. Therefore, by the law of gravitation, *M* will attract *H* more ſtrongly than it does *O*, by which, the diſtance between *H* and *O* will be increaſed: and a ſpectator on *O* will perceive *H* riſing higher toward *Z*. In like manner, *O* being more ſtrongly attracted than *D*, it will move farther towards *M* than *D* does: conſequently, the diſtance between *O* and *D* will be increaſed; and a ſpectator on *O*, not perceiving his own motion, will ſee *D* receding farther from him towards *n*: all effects and appearances being the ſame, whether *D* recedes from *O*, or *O* from *D*.

297. Suppoſe now there is a number of bodies, as *A*,*B*,*C*,*D*,*E*,*F*,*G*,*H* placed round *O*, ſo as to form a flexible or fluid ring: then, as the whole is attracted towards *M*, the parts at *H* and *D* will have their diſtance from *O* increaſed; whilſt the parts at *B* and *F*, being nearly at the ſame diſtance from *M* as *O* is, theſe parts will not recede from one another; but rather, by the oblique attraction of *M*, they will approach nearer to *O*. Hence, the fluid ring will form itſelf into an ellipſe *ZIBLnKFNZ*, whoſe longer Axis *nOZ* produced will paſs through *M*, and it's ſhorter Axis *BOF* will terminate in *B* and *F*. Let the ring be filled

filled with fluid particles, ſo as to form a ſphere round *O*; then, as the whole moves toward *M*, the fluid ſphere being lengthened at *Z* and *n*, will aſſume an oblong or oval form. If *M* is the Moon, *O* the Earth's center, *ABCDEFGH* the Sea covering the Earth's ſurface, it is evident, by the above reaſoning, that whilſt the Earth by it's gravity falls toward the Moon, the Water directly below her at *B* will ſwell and riſe gradually towards her: alſo the Water at *D* will recede from the center [ſtrictly ſpeaking, the center recedes from *D*] and riſe on the oppoſite ſide of the Earth: whilſt the Water at *B* and *F* is depreſſed, and falls below the former level. Hence, as the Earth turns round it's Axis from the Moon to the Moon again in 24¼ hours, there will be two Tides of Flood and two of Ebb in that time, as we find by experience.

298. As this explanation of the ebbing and flowing of the Sea is deduced from the Earth's conſtantly falling toward the Moon by the power of gravity, ſome may find a difficulty in conceiving how this is poſſible, when the Moon is full, or in oppoſition to the Sun; ſince the Earth revolves about the Sun, and muſt continually fall towards it, and therefore cannot fall contrary ways at the ſame time: or if the Earth is conſtantly falling towards the Moon, they muſt come together at laſt. To remove this difficulty, let it be conſidered, that it is not the center of the Earth that deſcribes the annual Orbit round the Sun, but the * common center of gravity of the Earth and Moon together: and that whilſt the Earth is

* This center is as much nearer the Earth's center than the Moon's as the Earth is heavier, or contains a greater quantity of matter than the Moon, namely, about 40 times. If both bodies were ſuſpended on it, they would hang in *equilibrio*. So that dividing 240,000 miles, the Moon's diſtance from the Earth's center, by 40, the exceſs of the Earth's weight above the Moon's, the quotient will be 6000 miles, which is the diſtance of the common center of gravity of the Earth and Moon from the Earth's center.

moving

PLATE IX. moving round the Sun, it alſo deſcribes a Circle round that center of gravity; going as many times round it in one revolution about the Sun as there are lunations or courſes of the Moon round the Earth in a year: and therefore, the Earth is conſtantly falling towards the Moon from a tangent to the Circle it deſcribes round the ſaid common center of gravity. Let *M* be the Moon, *T W* part of the Moon's Orbit, and *C* the center of gravity of the Earth and Moon: whilſt the Moon goes round her Orbit, the center of the Earth deſcribes the Circle *e g d* round *C*, to which Circle *g a k* is a tangent: and therefore, when the Moon has gone from *M* to a little paſt *W*, the Earth has moved from *g* to *e*; and in that time has fallen towards the Moon, from the tangent at *a* to *e*; and ſo round the whole Circle.

Fig. II.

299. The Sun's influence in raiſing the Tides is but ſmall in compariſon of the Moon's: For though the Earth's diameter bears a conſiderable proportion to it's diſtance from the Moon, it is next to nothing when compared with the diſtance of the Sun. And therefore, the difference of the Sun's attraction on the ſides of the Earth under and oppoſite to him, is much leſs than the difference of the Moon's attraction on the ſides of the Earth under and oppoſite to her: and therefore the Moon muſt raiſe the Tides much higher than they can be raiſed by the Sun.

Why the Tides are not higheſt when the Moon is on the Meridian.

300. On this Theory, ſo far as we have explained it, the Tides ought to be higheſt directly under and oppoſite to the Moon; that is, when the Moon is due north and ſouth. But we find, that in open Seas, where the water flows freely, the Moon *M* is generally paſt the north and ſouth Meridian, as at *p*, when it is high water at *Z* and at *n*. The reaſon is obvious; for though the Moon's attraction was to ceaſe altogether when ſhe was paſt the Meridian, yet the motion of aſcent commu-

Fig. I.

communicated to the water before that time would make it continue to rise for some time after; much more must it do so when the attraction is only diminished: as a little impulse given to a moving ball will cause it still to move farther than otherwise it could have done. And as experience shews, that the day is hotter about three in the afternoon, than when the Sun is on the Meridian, because of the encrease made to the heat already imparted. PLATE IX.

301. The Tides answer not always to the same distance of the Moon from the Meridian at the same places; but are variously affected by the action of the Sun, which brings them on sooner when the Moon is in her first and third Quarters, and keeps them back later when she is in her second and fourth: because, in the former case, the Tide raised by the Sun alone would be earlier than the Tide raised by the Moon; and in the latter case later. Nor always answer to her being at the same distance from it.

302. The Moon goes round the Earth in an elliptic Orbit, and therefore, in every Lunar Month, she approaches nearer to the Earth than her mean distance, and recedes farther from it. When she is nearest, she attracts strongest, and so raises the Tides most; the contrary happens when she is farthest, because of her weaker attraction. When both Luminaries are in the Equator, and the Moon in *Perigeo*, or at her least distance from the Earth, she raises the Tides highest of all, especially at her Conjunction and Opposition; both because the equatoreal parts have the greatest centrifugal force from their describing the largest Circle, and from the concurring actions of the Sun and Moon. At the Change, the attractive forces of the Sun and Moon being united, they diminish the gravity of the waters under the Moon, and their gravity on the opposite side is diminished by means of a greater centrifugal force. At the Full, whilst the Moon raises the Tide under and opposite to her, the Sun acting in the same line, raises the Tide Spring and neap Tides. Fig. VI.

under and oppoſite to him; whence their conjoint effect is the ſame as at the Change; and in both caſes, occaſion what we call *the Spring Tides.* But at the Quarters the Sun's action on the waters at *O* and *H* diminiſhes the effect of the Moon's action on the waters at *Z* and *N*; ſo that they riſe a little under and oppoſite to the Sun at *O* and *H*, and fall as much under and oppoſite to the Moon at *Z* and *N*; making what we call the *Neap Tides*, becauſe the Sun and Moon then act croſs-wiſe to each other. But, ſtrictly ſpeaking, theſe Tides happen not till ſome time after; becauſe in this, as in other caſes, § 300, the actions do not produce the greateſt effect when they are at the ſtrongeſt, but ſome time afterward.

Not greateſt at the Equinoxes, and why.

303. The Sun being nearer the Earth in Winter than in Summer, § 205, is of courſe nearer to it in *February* and *October* than in *March* and *September*; and therefore the greateſt Tides happen not till ſome time after the autumnal Equinox, and return a little before the vernal.

The Tides would not immediately ceaſe upon the annihilation of the Sun and Moon.

The Sea being thus put in motion, would continue to ebb and flow for ſeveral times, even though the Sun and Moon were annihilated, or their influence ſhould ceaſe: as if a baſon of water were agitated, the water would continue to move for ſome time after the baſon was left to ſtand ſtill. Or like a Pendulum, which having been put in motion by the hand, continues to make ſeveral vibrations without any new impulſe.

The lunar day, what. The Tides riſe to unequal heights in the ſame day, and why.

304. When the Moon is in the Equator, the Tides are equally high in both parts of the lunar day, or time of the Moon's revolving from the Meridian to the Meridian again, which is 24 hours 50 minutes. But as the Moon declines from the Equator towards either Pole, the Tides are alternately higher and lower at places having north or ſouth Latitude. For one of the higheſt elevations, which is that under the Moon, follows her towards the

PLATE IX. rotation carries them into the position $a\,T\,E$, on the side opposite to the Moon; the reverse happens at the same time in the southern Hemisphere $E\,S\,Q$, as is evident to sight. The Axis of the Tides $a\,C\,d$ has now it's Poles a and d (being always 90 degrees from the highest elevations) in the arctic and antarctic Circles; and therefore it is plain, that at these Circles there is but one Tide of Flood, and one of Ebb, in the lunar day. For, when the point a revolves half round to b, in 12 lunar hours, it has a Tide of Flood; but when it comes to the same point a again in 12 hours more,

Fig. IV. it has the lowest Ebb. In seven days afterward, the Moon M comes to the equinoctial Circle, and is over the Equator $E\,Q$, when both elevations describe the Equator; and in both Hemispheres, at equal distances from the Equator, the Tides are equally high in both parts of the lunar day. The

Fig. V. whole Phenomena being reversed, when the Moon has south declination, to what they were when her declination was north, require no farther description.

305. In the three last-mentioned Figures, the Earth is orthographically projected on the plane of the Meridian; but in order to describe a particular Phenomenon, we now project it on the plane of

Fig. VI. the Ecliptic. Let $H\,Z\,O\,N$ be the Earth and Sea, $F\,E\,D$ the Equator, T the Tropic of Cancer, C the arctic Circle, P the north Pole, and the Curves 1, 2, 3, &c. 24 Meridians, or Hour-circles, intersecting each other in the Poles; $A\,G\,M$ is the Moon's Orbit, S the Sun, M the Moon, Z the Water elevated under the Moon, and N the opposite equal Elevation. As the lowest parts of the Water are always 90 degrees from the highest, when the Moon is in either of the Tropics (as at M) the Elevation Z is on the Tropic of Capricorn, and the opposite Elevation N on the Tropic of Cancer, the low-water Circle $H\,C\,O$ touches the polar Circles at C; and the high-water Circle

When both Tides are equally high in the same day, they arrive at unequal intervals of Time; and *vice versâ*.

E T P 6

E ♈ P 6 goes over the Poles at *P*, and divides every parallel of Latitude into two equal ſegments. In this caſe the Tides upon every parallel are alternately higher and lower; but they return in equal times: the point ♈, for example, on the Tropic of Cancer (where the depth of the Tide is repreſented by the breadth of the dark ſhade) has a ſhallower Tide of Flood at ♈ than when it revolves half round from thence to 6, according to the order of the numeral Figures; but it revolves as ſoon from 6 to ♈ as it did from ♈ to 6. When the Moon is in the Equinoctial, the Elevations *Z* and *N* are transferred to the Equator at *O* and *H*, and the high and low-water Circles are got into each other's former places; in which caſe the Tides return in unequal times, but are equally high in both parts of the lunar day: for a place at 1 (under *D*) revolving as formerly, goes ſooner from 1 to 11 (under *F*) than from 11 to 1, becauſe the parallel it deſcribes is cut into unequal ſegments by the high-water Circle *HCO*: but the points 1 and 11 being equidiſtant from the Pole of the Tides at *C*, which is directly under the Pole of the Moon's Orbit *MGA*, the Elevations are equally high in both parts of the day.

306. And thus it appears, that as the Tides are governed by the Moon, they muſt turn on the Axis of the Moon's Orbit, which is inclined $23\frac{1}{2}$ degrees to the Earth's Axis at a mean ſtate: and therefore the Poles of the Tides muſt be ſo many degrees from the Poles of the Earth, or in oppoſite points of the polar Circles, going round theſe Circles in every lunar day. It is true, that according to Fig. IV, when the Moon is vertical to the Equator *EC♎*, the Poles of the Tides ſeem to fall in with the Poles of the World *N* and *S*: but when we conſider that *FGH* is under the Moon's Orbit, it will appear, that when the Moon is over *H*, in the Tropic of Capricorn, the north Pole of

the Tides (which can be no more than 90 degrees from under the Moon) muſt be at *c* in the arctic Circle, not at *N*, the north Pole of the Earth; and as the Moon aſcends from *H* to *G* in her Orbit, the north Pole of the Tides muſt ſhift from *c* to *a* in the arctic Circle, and the ſouth Pole as much in the antarctic.

It is not to be doubted, but that the Earth's quick rotation brings the Poles of the Tides nearer to the Poles of the World, than they would be if the Earth were at reſt, and the Moon revolved about it only once a month; for otherwiſe the Tides would be more unequal in their heights, and times of their returns, than we find they are. But how near the Earth's rotation may bring the Poles of it's Axis and thoſe of the Tides together, or how far the preceding Tides may affect thoſe which follow, ſo as to make them keep up nearly to the ſame heights, and times of ebbing and flowing, is a problem more fit to be ſolved by obſervation than by theory.

To know at what times we may expect the greateſt and leaſt Tides.

307. Thoſe who have opportunity to make obſervations, and chooſe to ſatisfy themſelves whether the Tides are really affected in the above manner by the different poſitions of the Moon, eſpecially as to the unequal times of their returns, may take this general rule for knowing when they ought to be ſo affected. When the Earth's Axis inclines to the Moon, the northern Tides, if not retarded in their paſſage through Shoals and Channels, nor affected by the Winds, ought to be greateſt when the Moon is above the Horizon, leaſt when ſhe is below it; and quite the reverſe when the Earth's Axis declines from her: but in both caſes, at equal intervals of time. When the Earth's Axis inclines ſidewiſe to the Moon, both Tides are equally high, but they happen at unequal intervals of time. In every Lunation the Earth's Axis inclines once to the Moon, once from her, and

and twice ſidewiſe to her, as it does to the Sun every year; becauſe the Moon goes round the Ecliptic every month, and the Sun but once in a year. In Summer, the Earth's Axis inclines towards the Moon when New; and therefore the day-tides in the north ought to be higheſt, and night-tides loweſt about the Change: at the Full the reverſe. At the Quarters they ought to be equally high, but unequal in their returns; becauſe the Earth's Axis then inclines ſidewiſe to the Moon. In Winter the Phenomena are the ſame at Full-Moon as in Summer at New. In Autumn the Earth's Axis inclines ſidewiſe to the Moon when New and Full; therefore the Tides ought to be equally high, and unequal in their returns at theſe times. At the firſt Quarter the Tides of Flood ſhould be leaſt when the Moon is above the Horizon, greateſt when ſhe is below it; and the reverſe at her third Quarter. In Spring, the Phenomena of the firſt Quarter anſwer to thoſe of the third Quarter in Autumn; and *vice verſâ*. The nearer any time is to either of theſe ſeaſons, the more the Tides partake of the Phenomena of theſe ſeaſons; and in the middle between any two of them the Tides are at a mean ſtate between thoſe of both.

Why the Tides riſe higher in Rivers than in the Sea.

308. In open Seas, the Tides riſe but to very ſmall heights in proportion to what they do in wide-mouthed rivers, opening in the Direction of the Stream of Tide. For, in Channels growing narrower gradually, the water is accumulated by the oppoſition of the contracting Bank. Like a gentle wind, little felt on an open plain, but ſtrong and briſk in a ſtreet; eſpecially if the wider end of the ſtreet be next the plain, and in the way of the wind.

The Tides happen at all diſtances of the Moon from the Meridian at different places, and why.

309. The Tides are ſo retarded in their paſſage through different Shoals and Channels, and otherwiſe ſo variouſly affected by ſtriking againſt Capes and Headlands, that to different places they happen at all diſtances of the Moon from the Meridian; conſe-

consequently at all hours of the lunar day. The Tide propagated by the Moon in the *German* Ocean, when she is three hours past the Meridian, takes 12 hours to come from thence to *London Bridge*; where it arrives by the time that a new Tide is raised in the Ocean. And therefore when the Moon has north declination, and we should expect the Tide at *London* to be greatest when the Moon is above the Horizon, we find it is least; and the contrary when she has south declination. At several places it is high water three hours before the Moon comes to the Meridian; but that Tide which the Moon pushes as it were before her, is only the Tide opposite to that which was raised by her when she was nine hours past the opposite Meridian.

The Water never rises in Lakes.

310. There are no Tides in Lakes, because they are generally so small, that when the Moon is vertical she attracts every part of them alike, and therefore by rendering all the water equally light, no part of it can be raised higher than another. The *Mediterranean* and *Baltic* Seas suffer very small elevations, because the Inlets by which they communicate with the Ocean are so narrow, that they cannot, in so short a time, receive or discharge enough to raise or sink their surfaces sensibly.

The Moon raises Tides in the Air.

311. Air being lighter than Water, and the surface of the Atmosphere being nearer to the Moon than the surface of the Sea, it cannot be doubted that the Moon raises much higher Tides in the Air than in the Sea. And therefore many have wondered why the Mercury does not sink in the Barometer when the Moon's action on the particles of Air makes them lighter as she passes over the Meridian. But we must consider, that as these particles are rendered lighter, a greater number of them is accumulated, until the deficiency of gravity be made up by the height of the column; and then there is an *equilibrium*, and con-

Why the Mercury in the Barometer is not affected by the aerial Tides.

sequently

ſequently an equal preſſure upon the Mercury as before; ſo that it cannot be affected by the aerial Tides.

CHAP. XVIII.

Of Eclipſes: Their Number and Periods. A large Catalogue of Ancient and Modern Eclipſes.

312. EVERY Planet and Satellite is illuminated by the Sun; and caſts a ſhadow towards that point of the Heavens which is oppoſite to the Sun. This ſhadow is nothing but a privation of light in the ſpace hid from the Sun by the opake body that intercepts his rays. A ſhadow, what.

313. When the Sun's light is ſo intercepted by the Moon, that to any place of the Earth the Sun appears partly or wholly covered, he is ſaid to undergo an Eclipſe; though properly ſpeaking, it is only an Eclipſe of that part of the Earth where the Moon's ſhadow or * Penumbra falls. When the Earth comes between the Sun and Moon, the Moon falls into the Earth's ſhadow; and having no light of her own, ſhe ſuffers a real Eclipſe from the interception of the Sun's rays. When the Sun is eclipſed to us, the Moon's Inhabitants on the ſide next the Earth (if any ſuch there be) ſee her ſhadow like a dark ſpot travelling over the Earth, about twice as faſt as it's equatoreal parts move, and the ſame way as they move. When the Moon is in an Eclipſe, the Sun appears eclipſed to her, total to all thoſe parts on which the Earth's ſhadow falls, and of as long continuance as they are in the ſhadow. Eclipſes of the Sun and Moon, what.

314. That the Earth is ſpherical (for the hills take off no more from the roundneſs of the Earth, than grains of duſt do from the roundneſs of a A proof that the Earth and Moon are globular bodies.

* The Penumbra is a faint kind of ſhadow all around the perfect ſhadow of the Planet or Satellite, and will be more fully explained by and by.

common

common Globe) is evident from the figure of its ſhadow on the Moon; which is always bounded by a circular line, although the Earth is inceſſantly turning it's different ſides to the Moon, and very ſeldom ſhews the ſame ſide to her in different Eclipſes, becauſe they ſeldom happen at the ſame hours. Were the Earth ſhaped like a round flat plate, it's ſhadow would only be circular when either of it's ſides directly faced the Moon; and more or leſs elliptical as the Earth happened to be turned more or leſs obliquely towards the Moon when ſhe is eclipſed. The Moon's different Phaſes prove her to be round, § 254; for, as ſhe keeps ſtill the ſame ſide towards the Earth, if that ſide were flat, as it appears to be, ſhe would never be viſible from the third Quarter to the firſt; and from the firſt Quarter to the third, ſhe would appear as round as when we ſay ſhe is Full: becauſe at the end of her firſt Quarter the Sun's light would come as ſuddenly on all her ſide next the Earth, as it does on a flat wall, and go off as abruptly at the end of her third Quarter.

And that the Sun is much bigger than the Earth, and the Moon much leſs.

315. If the Earth and Sun were equally big, the Earth's ſhadow would be infinitely extended, and all of the ſame bulk; and the Planet Mars, in either of it's Nodes and oppoſite to the Sun, would be eclipſed in the Earth's ſhadow. Were the Earth bigger than the Sun, it's ſhadow would increaſe in bulk the farther it extended, and would eclipſe the great Planets Jupiter and Saturn, with all their Moons, when they were oppoſite to the Sun. But as Mars in oppoſition never falls into the Earth's ſhadow, although he is not then above 42 millions of miles from the Earth, it is plain that the Earth is much leſs than the Sun; for otherwiſe it's ſhadow could not end in a point at ſo ſmall a diſtance. If the Sun and Moon were equally big, the Moon's ſhadow would go on to the Earth with an equal breadth, and cover a portion of the Earth's ſurface more than 2000 miles broad,

broad, even if it fell directly against the Earth's center, as seen from the Moon: and much more if it fell obliquely on the Earth: but the Moon's shadow is seldom 150 miles broad at the Earth, unless when it falls very obliquely on the Earth, in total Eclipses of the Sun. In annular Eclipses, the Moon's real shadow ends in a point at some distance from the Earth. The Moon's small distance from the Earth, and the shortness of her shadow, prove her to be less than the Sun. And, as the Earth's shadow is large enough to cover the Moon, if her diameter were three times as large as it is (which is evident from her long continuance in the shadow when she goes through it's center) it is plain, that the Earth is much bigger than the Moon.

316. Though all opake bodies on which the Sun shines have their shadows, yet such is the bulk of the Sun, and the distances of the Planets, that the primary Planets can never eclipse one another. A Primary can eclipse only it's Secondary, or be eclipsed by it; and never but when in opposition or conjunction with the Sun. The primary Planets are very seldom in these positions, but the Sun and Moon are so every month: whence one may imagine that these two Luminaries should be eclipsed every month. But there are few Eclipses in respect of the number of New and Full Moons; the reason of which we shall now explain.

The primary Planets never eclipse one another.

317. If the Moon's Orbit were coincident with the Plane of the Ecliptic, in which the Earth always moves and the Sun appears to move, the Moon's shadow would fall upon the Earth at every Change, and eclipse the Sun to some parts of the Earth. In like manner the Moon would go through the middle of the Earth's shadow, and be eclipsed at every Full; but with this difference, that she would be totally darkened for above an hour and half; whereas the Sun never was above four minutes totally eclipsed by the interposition of

Why there are so few Eclipses.

The Moon's Nodes.

of the Moon. But one half of the Moon's Orbit is elevated $5\frac{1}{3}$ degrees above the Ecliptic, and the other half as much depreſſed below it: conſequently, the Moon's Orbit interſects the Ecliptic in two oppoſite points called *the Moon's Nodes*, as has been already taken notice of, § 288. When theſe points are in a right line with the center of the Sun at New or Full Moon, the Sun, Moon and Earth, are all in a right line; and if the Moon be then New, her ſhadow falls upon the Earth; if Full, the Earth's ſhadow falls upon her. When

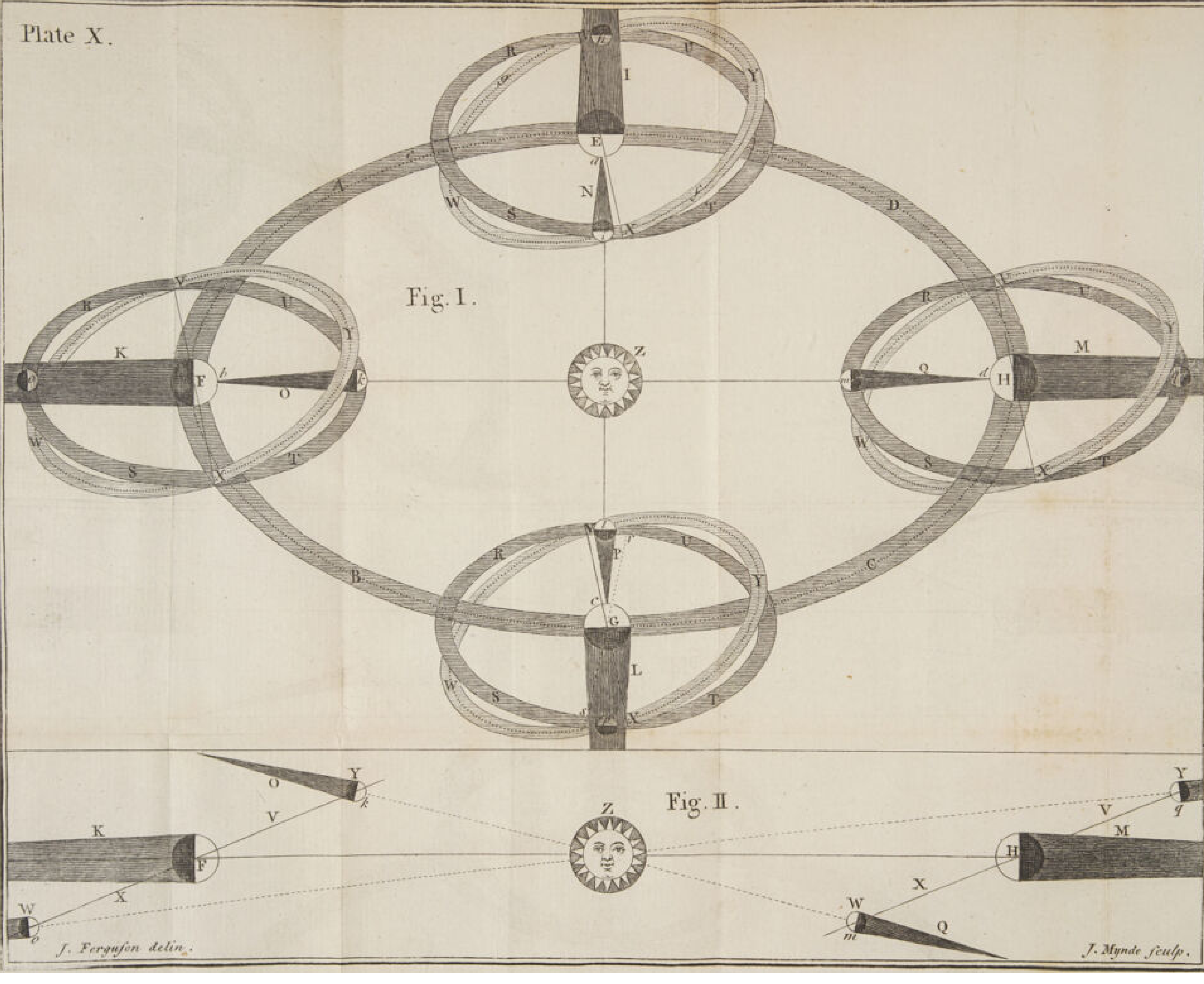
Limits of Eclipſes.

the Sun and Moon are more than 17 degrees from either of the Nodes at the time of Conjunction, the Moon is then generally too high or too low in her Orbit to caſt any part of her ſhadow upon the Earth. And when the Sun is more than 12 degrees from either of the Nodes at the time of Full Moon, the Moon is generally too high or too low in her Orbit to go through any part of the Earth's ſhadow: and in both theſe caſes there will be no Eclipſe. But when the Moon is leſs than 17 degrees from either Node at the time of Conjunction, her ſhadow or Penumbra falls more or leſs upon the Earth, as ſhe is more or leſs within this limit *. And when ſhe is leſs than 12 degrees from either Node at the time of Oppoſition, ſhe goes through a greater or leſs portion of the Earth's ſhadow, as ſhe is more or leſs within this limit. Her Orbit contains 360 degrees; of which 17, the limit of ſolar Eclipſes on either ſide of the Nodes, and 12, the limit of lunar Eclipſes, are but ſmall portions: and as the Sun commonly paſſes by the Nodes but twice in a year, it is no wonder that

* This admits of ſome variation: for, in apogeal Eclipſes, the ſolar limit is but $16\frac{1}{2}$ degrees; and in perigeal Eclipſes it is $18\frac{1}{3}$.——When the Full Moon is in her Apogee, ſhe will be eclipſed if ſhe be within $10\frac{1}{2}$ degrees of the Node; and when ſhe is full in her Perigee, ſhe will be eclipſed if ſhe be within $12\frac{1}{30}$ degrees of the Node.

we

Plate X.



J. Ferguson delin.

J. Mynde sculp.

we have so many New and Full Moons without Eclipses. PLATE X.

To illustrate this, let *A B C D* be the *Ecliptic*, *R S T U* a Circle lying in the same Plane with the Ecliptic, and *V W X Y* the *Moon's Orbit*, all thrown into an oblique view, which gives them an elliptical shape to the eye. One half of the Moon's Orbit, as *V W X*, is always below the Ecliptic, and the other half *X Y V* above it. The points *V* and *X*, where the Moon's Orbit intersects the Circle *R S T U*, which lies even with the Ecliptic, are the *Moon's Nodes*; and a right line, as *X E V*, drawn from one to the other, through the Earth's center, is called the *Line of the Nodes*, which is carried almost parallel to itself round the Sun in a year. Fig. I. Line of the Nodes.

If the Moon moved round the Earth in the Orbit *R S T U*, which is coincident with the Plane of the Ecliptic, her shadow would fall upon the Earth every time she is in conjunction with the Sun, and at every opposition she would go through the Earth's shadow. Were this the case, the Sun would be eclipsed at every Change, and the Moon at every Full, as already mentioned.

But although the Moon's shadow *N* must fall upon the Earth at *a*, when the Earth is at *E*, and the Moon in conjunction with the Sun at *i*, because she is then very near one of her Nodes; and at her opposition *n* she must go through the Earth's shadow *I*, because she is then near the other Node; yet, in the time that she goes round the Earth to her next Change, according to the order of the letters *X Y V W*, the Earth advances from *E* to *e*, according to the order of the letters *E F G H*, and the line of the Nodes *V E X* being carried nearly parallel to itself, brings the point *f* of the Moon's Orbit in conjunction with the Sun at that next Change; and then the Moon being at *f*, is too high above the Ecliptic to cast her shadow on the Earth: and as the Earth is still moving forward, the Moon at her next opposition will be at *g*, too

far

PLATE X. far below the Ecliptic to go through any part of the Earth's ſhadow; for by that time the point *g* will be at a conſiderable diſtance from the Earth as ſeen from the Sun.

When the Earth comes to *F*, the Moon in conjunction with the Sun *Z* is not at *k*, in a Plane coincident with the Ecliptic, but above it at *Y* in the higheſt part of her Orbit: and then the point *b* of her ſhadow *O* goes far above the Earth (as in Fig. II, which is an edge view of Fig. I.) The Moon at her next oppoſition is not at *o* (Fig. I.) but at *W*, where the Earth's ſhadow goes far above her (as in Fig. II.) In both theſe caſes the line of the Nodes *V F X* (Fig. I.) is about 90 degrees from the Sun, and both Luminaries are as far as poſſible from the limits of Eclipſes.

Fig. I. and II.

When the Earth has gone half round the Ecliptic from *E* to *G*, the line of the Nodes *V G X* is nearly, if not exactly, directed towards the Sun at *Z*; and then the New Moon *l* caſts her ſhadow *P* on the Earth *G*; and the Full Moon *p* goes through the Earth's ſhadow *L*; which brings on Eclipſes again, as when the Earth was at *E*.

When the Earth comes to *H*, the New Moon falls not at *m* in a plane coincident with the Ecliptic *C D*, but at *W* in her Orbit below it: and then her ſhadow *Q* (ſee Fig. II.) goes far below the Earth. At the next Full ſhe is not at *q* (Fig. I.) but at *Y* in her Orbit $5\frac{1}{3}$ degrees above *q*, and at her greateſt height above the Ecliptic *C D*; being then as far as poſſible, at any oppoſition, from the Earth's ſhadow *M* (as in Fig. II.)

So, when the Earth is at *E* and *G*, the Moon is about her Nodes at New and Full; and in her greateſt *North* and *South Declination* (or Latitude as it is generally called) from the Ecliptic at her Quarters: but when the Earth is at *F* or *H*, the Moon is in her greateſt *North* and *South Declination* from the Ecliptic at New and Full, and in the *Nodes* about her Quarters.

318. The

318. The point *X* where the Moon's Orbit crosses the Ecliptic is called *the Ascending Node*, because the Moon ascends from it above the Ecliptic: and the opposite point of intersection *V* is called *the Descending Node*, because the Moon descends from it below the Ecliptic. When the Moon is at *Y* in the highest point of her Orbit, she is in her greatest *North Latitude*; and when she is at *W* in the lowest point of her Orbit, she is in her greatest *South Latitude*.

PLATE X. The Moon's ascending and descending Node.

Her North and South Latitude.

319. If the line of the Nodes, like the Earth's Axis, was carried parallel to itself round the Sun, there would be just half a year between the conjunctions of the Sun and Nodes. But the Nodes shift backward, or contrary to the Earth's annual motion, $19\frac{1}{3}$ degrees every year; and therefore the same Node comes round to the Sun 19 days sooner every year than on the year before. Consequently, from the time that the ascending Node *X* (when the Earth is at *E*) passes by the Sun as seen from the Earth, it is only 173 days (not half a year) till the descending Node *V* passes by him. Therefore, in whatever time of the year we have Eclipses of the Luminaries about either Node, we may be sure that in 173 days afterward we shall have Eclipses about the other Node. And when at any time of the year the line of the Nodes is in the situation *V G X*, at the same time next year it will be in the situation *r G s*; the ascending Node having gone backward, that is, contrary to the order of Signs, from *X* to *s*, and the descending Node from *V* to *r*; each $19\frac{1}{3}$ degrees. At this rate the Nodes shift through all the signs and degrees of the Ecliptic in 18 years and 225 days; in which time there would always be a regular period of Eclipses, if any compleat number of Lunations were finished without a fraction. But this never happens; for if both the Sun and Moon should start from a line of conjunction with either of the Nodes in any point of the Ecliptic, the Sun would perform

The Nodes have a retrograde motion.

Fig. I.

Which brings on the Eclipses sooner every year than they would be if the Nodes had not such a motion.

perform 18 annual revolutions and 222 degrees over and above, and the Moon 230 Lunations and 85 degrees of the 231ſt, by the time the Node came round to the ſame point of the Ecliptic again: ſo that the Sun would then be 138 degrees from the Node, and the Moon 85 degrees from the Sun.

A period of Eclipſes.

320. But, in 223 mean Lunations, after the Sun, Moon, and Nodes, have been once in a line of conjunction, they return ſo nearly to the ſame ſtate again, as that the ſame Node, which was in conjunction with the Sun and Moon at the beginning of the firſt of theſe Lunations, will be within 28′ 12″ of a degree of a line of conjunction with the Sun and Moon again, when the laſt of theſe Lunations is compleated. And therefore, in that time, there will be a regular period of Eclipſes, or return of the ſame Eclipſe, for many ages.—In this period (which was firſt diſcovered by the *Chaldeans)* there are 18 *Julian* years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of *February* in Leap-years is four times included: but when it is five times included, the period conſiſts of only 18 years 10 days 7 hours 43 minutes 20 ſeconds. Conſequently, if to the mean time of any Eclipſe, either of the Sun or Moon, you add 18 *Julian* years 11 days 7 hours 43 minutes 20 ſeconds, when the laſt day of *February* in Leap-years comes in four times, or a day leſs when it comes in five times, you will have the mean time of the return of the ſame Eclipſe.

But the falling back of the line of conjunctions or oppoſitions of the Sun and Moon 28′ 12″ with reſpect to the line of the Nodes in every period, will wear it out in proceſs of time; and after that, it will not return again in leſs than 12492 years.—Theſe Eclipſes of the Sun, which happen about the Aſcending Node, and begin to come in at the North Pole of the Earth, will go a little ſoutherly at each return, till they go quite off the Earth at the

the South Pole; and thoſe which happen about the Deſcending Node, and begin to come in at the South Pole of the Earth, will go a little northerly at each return, till at laſt they quite leave the Earth at the North Pole.

To exemplify this matter, we ſhall firſt conſider the Sun's Eclipſe, *March* 21ſt Old Stile (*April* 1ſt New Stile) A. D. 1764, according to it's mean revolutions, without equating the times, or the Sun's diſtance from the Node; and then according to it's true equated times.

This Eclipſe fell in the open ſpace at each return, quite clear of the Earth, ever ſince the creation till A. D. 1295, *June* 13th Old Stile, at 12 h. 52 m. 59 ſec. *poſt meridiem*, when the Moon's ſhadow firſt touched the Earth at the North Pole; the Sun being then 17° 48′ 27″ from the Aſcending Node.—In each period ſince that time, the Sun has come 28′ 12″ nearer and nearer the ſame Node, and the Moon's ſhadow has therefore gone more and more ſoutherly.—In the year 1962, *July* 18th Old Stile, at 10 h. 36 m. 21 ſec. *p. m.* when the ſame Eclipſe will have returned 38 times, the Sun will be only 24′ 45″ from the Aſcending Node, and the center of the Moon's ſhadow will fall a little northward of the Earth's center.—At the end of the next following period, A. D. 1980, *July* 28th Old Stile, at 18 h. 19 m. 41 ſec. *p. m.* the Sun will have receded back 3′ 27″ from the Aſcending Node, and the Moon will have a very ſmall degree of ſouthern Latitude, which will cauſe the center of her ſhadow to paſs a very ſmall matter ſouth of the Earth's center.—After which, in every following period, the Sun will be 28′ 12″ farther back from the Aſcending Node than in the period laſt before; and the Moon's ſhadow will go ſtill farther and farther ſouthward, until *September* 12th Old Stile, at 23 h. 46 m. 22 ſec. *p. m.* A. D. 2665; when the Eclipſe will have compleated it's 77th periodical return, and will go quite off the Earth at the South Pole (the Sun being then 17° 55′ 22″ back from the Node) and it cannot come in at the North Pole, so as to begin the same Course over again, in less then 12492 years afterward.—And such will be the case of every other Eclipse of the Sun: for, as there is about 18 degrees on each side of the Node within which there is a possibility of Eclipses, their whole revolution goes through 36 degrees about that Node, which taken from 360 degrees, leaves remaining 324 degrees for the Eclipses to travel *in expansum*. And as this 36 degrees is not gone through in less than 77 periods, which takes up 1388 years, the remaining 324 degrees cannot be so gone through in less than 12492 years. For, as 36 is to 1388, so is 324 to 12492.

321. In order to shew both the mean and true times of the returns of this Eclipse, through all it's periods, together with the mean Anomalies of the Sun and Moon, at each return, and the mean and true distances of the Sun from the Moon's Ascending Node, and the Moon's true Latitude at the true time of each New Moon, I have calculated the following Tables for the sake of those who may choose to project this Eclipse at any of it's returns, according to the rules laid down in the 15th Chapter; and have thereby taken by much the greatest part of the trouble off their hands.—All the times are according to the Old Stile, for the sake of a regularity which, with respect to the nominal days of the Months, does not take place in the New: but by adding the days difference of Stiles, they are reduced to the times which agree with the New Stile.

According to the mean (or supposed equable) motions of the Sun, Moon, and Nodes, the Moon's shadow in this Eclipse would have first touched the Earth at the North Pole, on the 13th of *June*, A. D. 1295, at 12 h. 52 m. 59 sec. past Noon on the meridian of *London*; and would quite leave the Earth

Earth at the South Pole, on the 12th of *September*, A. D. 2665, at 23 h. 46 m. 22 ſec. paſt Noon, at the completion of it's 77th period; as ſhewn by the firſt and ſecond Tables.

But, on account of the true (or unequable) motions of the Sun, Moon, and Nodes, the firſt coming-in of this Eclipſe, at the North Pole of the Earth, was on the 24th of *June*, A. D. 1313, at 3 h. 57 m. 3 ſec. paſt Noon; and it will finally leave the Earth at the South Pole, on the 31ſt of *July*, A. D. 2593, at 10 h. 25 m. 31 ſec. paſt Noon, at the completion of it's 72d period; as ſhewn by the third and fourth Tables.—So that, the true motions do not only alter the true times from the mean, but they alſo cut off five periods from thoſe of the mean returns of this Eclipſe.

TABLE I. *The mean Time of New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, at the mean Time of each periodical Return of the Sun's Eclipse,* March 21*st*, 1764, *from it's first coming upon the Earth since the Creation, till it falls right against the Earth's center, according to the Old Stile.*

Periodical Returns.	Years of Christ.	Mean Time of New Moon.					Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
		Month.	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
0	1277	June	2	5	9	35	11	17	57	4	1	26	31	42	0	18	16	40
1	1295	June	13	12	52	5	1	28	27	32	1	23	40	19	0	17	48	27
2	1313	June	23	20	36	15	0	8	57	35	1	20	48	56	0	17	20	15
3	1331	July	5	4	19	3	0	19	27	32	1	17	57	33	0	16	52	2
4	1349	July	15	12	2	55	0	29	57	2	1	15	6	10	0	16	23	50
5	1367	July	26	19	46	19	1	10	27	2	1	12	14	47	0	15	55	37
6	1385	Aug.	6	3	29	35	1	20	57	23	1	9	23	24	0	15	27	25
7	1403	Aug.	17	11	12	5	2	1	27	20	1	6	32	1	0	14	59	12
8	1421	Aug.	27	18	56	15	2	11	57	17	1	3	40	38	0	14	31	0
9	1439	Sept.	8	2	39	3	2	22	27	14	1	0	49	15	0	14	2	47
10	1457	Sept.	18	10	2	55	3	2	57	11	0	27	57	52	0	13	34	35
11	1475	Sept.	29	18	6	15	3	13	27	8	0	25	6	29	0	13	6	22
12	1493	Oct.	10	1	49	35	3	23	57	5	0	22	15	6	0	12	38	10
13	1511	Oct.	21	9	32	5	4	4	27	2	0	19	23	43	0	12	9	57
14	1529	Oct.	31	17	16	15	4	14	56	59	0	16	32	20	0	11	41	45
15	1547	Nov.	12	0	59	40	4	25	26	56	0	13	40	57	0	11	13	32
16.	1565	Nov.	22	8	43	0	5	5	56	53	0	10	49	34	0	10	45	20
17	1583	Dec.	3	16	26	20	5	16	26	50	0	7	58	9	0	10	17	7
18	1601	Dec.	14	0	9	40	5	26	56	47	0	5	6	46	0	9	48	55
19	1619	Dec.	25	7	53	0	6	7	26	44	0	2	15	25	0	9	20	42
20	1638	Jan.	4	15	36	20	6	17	56	41	11	29	24	2	0	8	52	30
21	1656	Jan.	15	23	19	40	6	28	26	38	11	26	32	39	0	8	24	17
22	1674	Jan.	26	7	3	0	7	8	56	35	11	23	41	16	0	7	56	5
23	1692	Feb.	6	14	46	20	7	19	25	32	11	20	49	53	0	7	27	52
24	1710	Feb.	16	22	29	40	7	29	56	29	11	17	58	30	0	6	59	40
25	1728	Feb.	28	6	13	0	8	10	26	26	11	15	7	7	0	6	31	27
26	1746	Mar.	10	13	56	20	8	20	56	23	11	12	15	44	0	6	3	15
27	1764	Mar.	20	21	39	40	9	1	26	20	11	9	24	21	0	5	35	2
28	1782	April	1	5	23	0	9	11	56	17	11	6	32	58	0	5	6	50
29	1800	April	11	13	6	20	9	22	26	14	11	3	41	35	0	4	38	37
30	1818	April	22	20	49	40	10	2	56	11	11	0	50	12	0	4	10	25
31	1836	May	3	4	33	0	10	13	26	8	10	27	58	49	0	3	42	12
32	1854	May	14	12	16	20	10	23	56	5	10	25	7	26	0	3	14	0
33	1872	May	24	19	59	40	11	4	26	2	10	22	16	3	0	2	45	47
34	1890	June	5	3	43	0	11	14	55	59	10	19	24	40	0	2	17	35
35	1908	June	15	11	26	20	11	25	25	56	10	16	33	17	0	1	49	22
36	1926	June	26	19	9	40	0	5	55	53	10	13	41	54	0	1	21	10
37	1944	July	7	2	53	0	0	16	25	50	10	10	50	31	0	0	52	57
38	1962	July	18	10	36	21	0	26	55	47	10	7	59	8	0	0	24	45

TABL

TABLE II. *The mean Time of New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, at the mean Time of each periodical Return of the Sun's Eclipse,* March 21*st*, 1764, *from the mean Time of it's falling right against the Earth's center, till it finally leaves the Earth, according to the Julian or Old Stile.*

Periodical Returns.	Years of Christ.	Mean Time of New Moon.					Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
		Month.	D.	H.	M.	S.	s	o	′	″	s	o	′	″	s	o	′	″
39	1980	July	28	18	19	41	1	7	25	44	10	5	7	45	11	29	56	33
40	1998	Aug.	9	2	3	1	1	17	55	41	10	2	1[illegible]	22	11	29	28	20
41	2016	Aug.	19	9	46	21	1	28	25	38	9	29	24	59	11	29	0	8
42	2034	Aug.	30	17	29	41	2	8	55	36	9	26	33	36	11	28	31	55
43	2052	Sept.	10	1	13	1	2	19	25	33	9	23	42	13	11	28	3	43
44	2070	Sept.	21	8	56	21	2	29	55	32	9	20	50	50	11	27	35	30
45	2088	Oct.	1	16	39	41	3	10	25	27	9	17	59	27	11	27	7	18
46	2106	Oct.	13	0	23	1	3	20	55	24	9	15	8	4	11	26	39	5
47	2124	Oct.	23	8	6	21	4	1	25	21	9	12	16	41	11	26	10	53
48	2142	Nov.	3	15	49	41	4	11	55	18	9	9	25	18	11	25	42	40
49	2160	Nov.	13	23	31	1	4	22	25	15	9	6	33	56	11	25	14	28
50	2178	Nov.	25	7	16	21	5	2	55	12	9	3	42	33	11	24	46	15
51	2196	Dec.	5	14	59	41	5	13	25	9	9	0	51	10	11	24	18	3
52	2214	Dec.	16	22	43	1	5	23	55	7	8	27	59	47	11	23	49	50
53	2232	Dec.	27	6	26	21	6	4	25	4	8	25	8	24	11	23	21	38
54	2251	Jan.	7	14	9	41	6	14	55	1	8	22	17	1	11	22	53	25
55	2269	Jan.	17	21	53	1	6	25	24	58	8	19	25	38	11	22	15	13
56	2287	Jan.	29	5	36	21	7	5	54	55	8	16	31	15	11	21	57	0
57	2305	Feb.	8	13	19	41	7	16	24	52	8	13	42	52	11	21	28	48
58	2323	Feb.	19	21	3	1	7	26	54	49	8	10	51	29	11	21	0	35
59	2341	Mar.	2	4	46	21	8	7	24	46	8	8	0	6	11	20	32	23
60	2359	Mar.	13	12	29	42	8	17	54	43	8	5	8	43	11	20	4	10
61	2377	Mar.	23	20	13	2	8	28	24	40	8	2	17	20	11	19	35	58
62	2395	Apr.	4	3	56	22	9	8	54	37	7	29	25	57	11	19	7	45
63	2413	Apr.	14	11	39	42	9	19	24	34	7	26	34	34	11	18	39	33
64	2431	Apr.	25	19	23	2	9	29	54	31	7	23	43	11	11	18	11	20
65	2449	May	6	3	6	22	10	10	24	28	7	20	51	48	11	17	43	8
66	2467	May	17	10	49	42	10	20	54	2[illegible]	7	18	0	25	11	17	14	54
67	2485	May	27	18	33	2	11	1	24	22	7	15	9	2	11	16	46	43
68	2503	June	8	2	1[illegible]	2[illegible]	11	11	54	1[illegible]	7	12	17	3[illegible]	11	16	18	31
69	2521	June	18	9	59	42	11	22	24	1[illegible]	7	9	26	1[illegible]	11	15	50	18
70	2539	June	29	17	43	2	0	2	54	14	7	6	34	5	11	15	22	6
71	2557	July	10	1	26	22	0	13	24	11	7	3	43	30	11	14	53	54
72	2575	July	21	9	9	42	0	23	54	8	7	0	52	[illegible]	11	14	25	41
73	2593	July	31	16	53	2	1	4	24	5	6	28	0	44	11	13	57	28
74	2611	Aug.	12	0	30	22	1	14	54	2	6	25	9	21	11	13	29	16
75	2629	Aug.	22	8	19	42	1	25	23	59	6	22	17	58	11	13	1	3
76	2647	Sept.	2	16	3	2	2	5	53	5[illegible]	6	19	26	3[illegible]	11	12	32	51
77	2665	Sept.	12	23	46	22	2	16	23	5[illegible]	6	16	35	12	11	12	4	38

TABLE III. *The true Time of New Moon, with the Sun's true Diſtance from the Moon's Aſcending Node, and the Moon's true Latitude, at the true Time of each periodical Return of the Sun's Eclipſe, March 21ſt, Old Stile, A. D. 1706, from the Time of it's firſt coming upon the Earth ſince the Creation till it falls right againſt the Earth's center.*

Periodical Returns	Years of Chriſt.	True Time of New Moon					Sun's true Diſtance from the Node.				Moon's true Latitude, North.			
		Month.	D	H.	M.	S.	s	o	′	″	o	′	″	Nor.
0	1295	June	13	21	54	32	0	18	40	54	1	33	45	N. A.
1	1313	June	24	3	57	3	0	17	20	22	1	29	34	N. A.
2	1331	July	5	10	42	8	0	16	29	35	1	25	20	N. A.
3	1349	July	15	17	14	15	0	15	34	18	1	20	45	N. A.
4	1367	July	26	23	49	21	0	14	46	8	1	16	39	N. A.
5	1385	Aug.	6	6	41	17	0	13	59	43	1	12	43	N. A.
6	1403	Aug.	17	13	32	19	0	13	16	44	1	9	3	N. A.
7	1421	Aug.	27	20	30	17	0	12	37	4	1	5	42	N. A.
8	1439	Sept.	8	3	51	46	0	12	1	54	1	2	41	N. A.
9	1457	Sept.	18	10	23	11	0	11	30	27	0	58	53	N. A
10	1475	Sept.	29	17	57	7	0	11	3	56	0	57	43	N. A.
11	1493	Oct.	10	1	44	3	0	10	41	55	0	55	49	N. A.
12	1511	Oct.	21	9	29	53	0	10	25	11	0	54	28	N. A.
13	1529	Oct.	31	17	9	18	0	10	11	27	0	53	12	N. A.
14	1547	Nov.	12	0	51	25	0	10	1	10	0	52	19	N. A.
15	1565	Nov.	22	8	54	56	0	9	52	49	0	51	46	N. A.
16	1583	Dec.	3	16	48	17	0	9	48	4	0	51	11	N. A.
17	1601	Dec	14	0	51	5	0	9	43	42	0	50	49	N A.
18	1619	Dec.	25	8	54	59	0	9	40	23	0	50	31	N. A.
19	1638	Jan.	4	16	56	1	0	9	34	57	0	50	3	N. A.
20	1656	Jan.	16	0	54	41	0	9	29	24	0	49	57	N. A.
21	1674	Jan.	26	8	48	24	0	9	19	44	0	48	44	N. A.
22	1692	Feb.	6	16	36	28	0	9	8	58	0	47	49	N. A.
23	1710	Feb.	17	0	8	37	0	8	54	20	0	46	44	N. A.
24	1728	Feb.	28	7	43	40	0	8	34	53	0	44	52	N. A.
25	1746	Mar.	10	15	14	33	0	8	10	38	0	42	46	N. A
26	1764	Mar.	21	22	30	26	0	7	42	14	0	40	18	N. A.
27	1782	Apr.	1	5	37	[illegible]	0	7	9	27	0	37	28	N. A.
28	1800	Apr.	11	12	36	38	0	6	35	30	0	34	31	N. A.
29	1818	Apr.	22	19	27	34	0	5	51	48	0	30	43	N. A.
30	1836	May	3	2	12	7	0	5	5	5	0	26	40	N. A.
31	1854	May	13	8	50	4	0	4	19	45	0	22	42	N. A.
32	1872	May	24	15	28	15	0	3	26	3	0	18	1	N. A.
33	1890	June	4	22	8	[illegible]	0	2	35	5	0	13	34	N. A.
34	1908	June	15	4	38	23	0	1	41	43	0	8	54	N. A.
35	1926	June	26	11	13	[illegible]	0	0	47	28	0	4	10	N. A.

On account of the differences between the mean and true New Moons, and between the Sun's mean and true Diſtances from the Node, the Moon's ſhadow falls even with the Earth's center two periods ſooner in this Table than in the firſt.

TABLE IV. *The true Time of New Moon, with the Sun's true Distance from the Moon's Ascending Node, and the Moon's true Latitude, at each periodical Return of the Sun's Eclipse,* March 21*st, Old Stile,* A. D. 1764, *from it's falling right against the Earth's center, till it finally leaves the Earth.*

Periodical Returns.	Years of Christ.	True Time of New Moon.					Sun's true Distance from the Node.				Moon's true Latitude, South.			
		Month.	D.	H.	M.	S.	s	°	′	″	°	′	″	South
36	1944	July	6	17	50	35	11	29	55	28	0	0	24	S. A.
37	1962	July	18	0	31	38	11	29	2	35	0	5	2	S. A.
38	1980	July	28	7	18	53	11	28	11	32	0	9	29	S. A.
39	1998	Aug.	8	14	12	22	11	27	26	41	0	13	25	S. A.
40	2016	Aug.	18	21	14	53	11	26	42	16	0	17	18	S. A.
41	2034	Aug.	30	4	25	45	11	26	2	0	0	20	48	S. A.
42	2052	Sept.	9	11	45	17	11	25	20	46	0	23	53	S. A.
43	2070	Sept.	20	19	17	26	11	24	55	4	0	26	39	S. A.
44	2088	Oct.	1	2	57	8	11	24	27	43	0	28	58	S. A.
45	2106	Oct.	12	10	47	39	11	24	4	38	0	31	2	S. A.
46	2124	Oct.	22	18	37	40	11	23	48	28	0	32	20	S. A.
47	2142	Nov.	3	2	56	19	11	23	35	11	0	33	53	S. A.
48	2160	Nov.	13	11	11	20	11	23	22	22	0	34	42	S. A.
49	2178	Nov.	24	19	36	14	11	23	18	57	0	35	0	S. A.
50	2196	Dec	5	4	4	9	11	23	14	40	0	35	22	S. A.
51	2214	Dec.	16	12	35	48	11	23	10	43	0	35	43	S. A.
52	2232	Dec.	26	20	29	9	11	23	6	47	0	36	1	S. A.
53	2251	Jan.	7	5	42	9	11	23	4	27	0	36	16	S. A
54	2269	Jan.	17	14	14	8	11	23	0	41	0	36	35	S. A.
55	2287	Jan.	28	22	43	34	11	22	53	58	0	37	10	S. A.
56	2305	Feb.	8	7	8	30	11	22	44	44	0	37	59	S. A.
57	2323	Feb.	19	15	7	10	11	22	31	1	0	39	8	S. A.
58	2341	Mar.	2	0	6	5	11	22	17	46	0	40	28	S. A.
59	2359	Mar.	13	7	59	17	11	21	55	29	0	42	9	S. A.
60	2377	Mar.	23	15	51	59	11	21	39	40	0	43	41	S. A.
61	2395	Apr.	3	23	45	7	11	21	0	53	0	46	58	S. A.
62	2413	Apr.	14	7	32	40	11	20	26	22	0	49	48	S. A.
63	2431	Apr.	25	15	12	57	11	19	47	34	0	53	17	S A
64	2449	May	5	22	45	14	11	19	6	22	0	56	50	S. A.
65	2467	May	17	6	17	30	11	18	21	16	1	0	40	S A.
66	2485	May	27	13	46	29	11	7	34	20	1	4	42	S. A.
67	2503	June	7	21	10	31	11	16	43	17	1	9	3	S. A.
68	2521	June	18	4	24	42	11	15	51	48	1	13	26	S. A.
69	2539	June	29	11	58	46	11	15	1	12	1	17	43	S. A.
70	2557	July	9	19	24	7	11	14	9	13	1	22	6	S. A.
71	2575	July	21	2	52	34	11	13	19	22	1	26	16	S. A.
72	2593	July	31	10	25	31	11	12	13	43	1	31	44	S. A.
0	2611	Aug.	11	17	58	39	11	11	45	13	1	36	13	S. A.

By the true Motions of the Sun, Moon, and Nodes, this Eclipse goes off the Earth four Periods sooner than it would have done by mean equable Motions.

From Mr. G. SMITH's dissertation on Eclipses, printed at *London*, by E. CAVE, in the year 1748.

" To illuſtrate this a little farther, we ſhall exa-" mine ſome of the moſt remarkable circumſtances " of the returns of the Eclipſe which happened " *July* 14, 1748, about noon. This Eclipſe, after " traverſing the voids of ſpace from the Creation, " at laſt began to enter the *Terra Auſtralis Incog-" nita*, about 88 years after the Conqueſt, which " was the laſt of King STEPHEN's reign; every " * *Chaldean* period it has crept more northerly, " but was ſtill inviſible in *Britain* before the year " 1622; when on the 30th of *April* it began to " touch the ſouth parts of *England* about 2 in the " afternoon; it's central appearance riſing in the " *American* South Seas, and traverſing *Peru* and " the *Amazon*'s country, through the *Atlantic* ocean " into *Africa*, and ſetting in the *Æthiopian* conti-" nent, not far from the beginning of the Red Sea.

" It's next viſible period was after three *Chaldean* " revolutions in 1676, on the firſt of *June*, riſing " central in the *Atlantic* ocean, paſſing us about " 9 in the morning, with four † Digits eclipſed on " the under limb; and ſetting in the gulph of " *Cochinchina* in the *Eaſt-Indies*.

" It being now near the Solſtice, this Eclipſe " was viſible the very next return in 1694, in the " evening; and in two periods more, which was " in 1730, on the 4th of *July*, was ſeen above half " eclipſed juſt after Sun-riſe, and obſerved both " at *Wirtemberg* in *Germany*, and *Pekin* in *China*, " ſoon after which it went off.

" Eighteen years more afforded us the Eclipſe " which fell on the 14th of *July* 1748.

" The next viſible return will happen on *July* " 25, 1766, in the evening, about four Digits " eclipſed; and after two periods more, on *Auguſt*

* The above period of 18 years 11 days 7 hours 43 minutes 20 ſeconds, which was found out by the *Chaldeans*, and by them called *Saros*.

† A Digit is a twelfth part of the diameter of the Sun or Moon.

" 16th,

"16th, 1802, early in the morning, about five "Digits, the center coming from the north frozen "continent, by the capes of *Norway*, through "*Tartary*, *China*, and *Japan*, to the *Ladrone* islands, "where it goes off.

"Again, in 1820, *August* 26, betwixt one and "two, there will be another great Eclipse at *London*, "about 10 Digits; but happening so near the "Equinox, the center will leave every part of "*Britain* to the West, and enter *Germany* at *Emb-*"*den*, passing by *Venice*, *Naples*, *Grand Cairo*, and "set in the gulf of *Bassora* near that city.

"It will be no more visible till 1874, when five "Digits will be obscured (the center being now "about to leave the Earth) on *September* 28. In "1892 the Sun will go down eclipsed at *London*, "and again in 1928 the passage of the center will "be in the *expansum*, though there will be two "Digits eclipsed at *London*, *October* the 31st of "that year; and about the year 2090 the whole "Penumbra will be wore off; whence no more "returns of this Eclipse can happen till after a re-"volution of 10 thousand years.

"From these remarks on the intire revolution "of this Eclipse, we may gather, that a thousand "years, more or less (for there are some irregula-"rities that may protract or lengthen this period "100 years) complete the whole terrestrial Phe-"nomena of any single Eclipse: and since 20 pe-"riods of 54 years each, and about 33 days, com-"prehend the intire extent of their revolution, it "is evident that the times of the returns will pass "through a circuit of one year and ten Months, "every *Chaldean* period being ten or eleven days "later, and of the equable appearances about 32 "or 33 days. Thus, though this Eclipse happens "about the middle of *July*, no other subsequent "Eclipse of this period will return to the middle "of the same month again; but wear constantly "each period 10 or 11 days forward; and at last

"appear

" appear in Winter, but then it begins to ceafe from " affecting us.

" Another conclufion from this revolution may " be drawn, that there will feldom be any more " than two great Eclipfes of the Sun in the interval " of this period, and thefe follow fometimes next " return, and often at greater diftances. That of " 1715 returned again in 1733 very great; but " this prefent Eclipfe will not be great till the " arrival of 1820, which is a revolution of four " *Chaldean* periods: fo that the irregularities of " their circuits muft undergo new computations to " affign them exactly.

" Nor do all Eclipfes come in at the fouth Pole: " *that* depends altogether on the pofition of the " lunar Nodes, which will bring in as many from " the *expanfum* one way as the other; and fuch " Eclipfes will wear more foutherly by degrees, " contrary to what happens in the prefent cafe.

" The Eclipfe, for example, of 1736, in *Sep-* " *tember*, had it's center in the *expanfum*, and fet " about the middle of it's obfcurity in *Britain*; it " will wear in at the north Pole, and in the year " 2600, or thereabouts, go off in the *expanfum* on " the fouth fide of the Earth.

" The Eclipfes therefore which happened about " the Creation are little more than half way yet " of their ethereal circuit; and will be 4000 years " before they enter the Earth any more. This " grand revolution feems to have been entirely " unknown to the antients.

Why our prefent Tables agree not with antient obfervations.

322. " It is particularly to be noted, that Eclipfes " which have happened many centuries ago, will " not be found by our prefent Tables to agree ex- " actly with antient obfervations, by reafon of the " great Anomalies in the lunar motions; which " appears an inconteftable demonftration of the " non-eternity of the Univerfe. For it feems con- " firmed by undeniable proofs, that the Moon now " finifhes her period in lefs time than formerly,

" and

"and will continue by the centripetal law to ap-
"proach nearer and nearer the Earth, and to go
"ſooner and ſooner round it: nor will the centri-
"fugal power be ſufficient to compenſate the dif-
"ferent gravitations of ſuch an aſſemblage of
"bodies as conſtitute the ſolar ſyſtem, which would
"come to ruin of itſelf, without ſome new regu-
"lation and adjuſtment of their original motions*.

323. "We are credibly informed from the teſti- THALES's Eclipſe.
"mony of the antients, that there was a total
"Eclipſe of the Sun predicted by THALES to hap-
"pen in the fourth year of the 48th † *Olympiad*,
"either

* There are two antient Eclipſes of the Moon, recorded by *Ptolemy* from *Hipparchus*, which afford an undeniable proof of the Moon's acceleration. The firſt of theſe was obſerved at *Babylon*, *December* the 22d, in the year before CHRIST 383: when the Moon began to be eclipſed about half an hour before the Sun roſe, and the Eclipſe was not over before the Moon ſet: but by moſt of our Aſtronomical Tables, the Moon was ſet at *Babylon* half an hour before the Eclipſe began; in which caſe, there could have been no poſſibility of obſerving it. The ſecond Eclipſe was obſerved at *Alexandria*, *September* the 22d, the year before CHRIST 201; where the Moon roſe ſo much eclipſed, that the Eclipſe muſt have begun about half an hour before ſhe roſe: whereas, by moſt of our Tables, the beginning of this Eclipſe was not till about 10 minutes after the Moon roſe at *Alexandria*. Had theſe Eclipſes begun and ended while the Sun was below the Horizon, we might have imagined, that as the antients had no certain way of meaſuring time, they might have been ſo far miſtaken in the hours, that we could not have laid any ſtreſs on the accounts given by them. But, as in the firſt Eclipſe the Moon was ſet, and conſequently the Sun riſen, before it was over; and in the ſecond Eclipſe the Sun was ſet and the Moon not riſen, till ſome time after it began; theſe are ſuch circumſtances as the obſervers could not poſſibly be miſtaken in. Mr. *Struyk*, in the following Catalogue, notwithſtanding the expreſs words of *Ptolemy*, puts down theſe two Eclipſes as obſerved at *Athens*; where they might have been ſeen as above, without any acceleration of the Moon's motion: *Athens* being 20 degrees Weſt of *Babylon*, and 7 degrees Weſt of *Alexandria*.

† Each *Olympiad* began at the time of Full Moon next after the Summer Solſtice, and laſted four years, which were of unequal lengths, becauſe the time of Full Moon differs 11 days every year: ſo that they might ſometimes begin on the next day

"either at *Sardis* or *Miletus* in *Asia*, where THALES "then resided. That year corresponds to the "585th year before CHRIST; when accordingly "there happened a very signal eclipse of the Sun, "on the 28th of *May*, answering to the present "10th of that month*, central through *North* "*America*, the south parts of *France*, *Italy*, &c. as "far as *Athens*, or the Isles in the *Ægean* Sea; "which is the farthest that even the *Caroline* Tables "carry it; and consequently make it invisible to "any part of *Asia*, in the total character; though "I have good reasons to believe that it extended "to *Babylon*, and went down central over that city. "We are not however to imagine, that it was set

day after the Solstice, and at other times not till four weeks after it. The first *Olympiad* began in the year of the Julian Period 3938, which was 776 years before the first year of CHRIST, or 775 before the year of his birth; and the last *Olympiad*, which was the 293d, began *A. D.* 393. At the expiration of each *Olympiad*, the *Olympic Games* were celebrated in the *Elean* fields, near the river *Alpheus* in the *Peloponnesus* (now *Morea*) in honour of JUPITER OLYMPUS. See STRAUCHIUS's *Breviarium Chronologium*, p. 247—251.

* The reader may probably find it difficult to understand why Mr. SMITH should reckon this Eclipse to have been in the 4th year of the 48th *Olympiad*, as it was only in the end of the third year: and also why the 28th of *May*, in the 585th year before CHRIST, should answer to the present 10th of that Month. But we hope the following explanation will remove these difficulties.

The month of *May* (when the Sun was eclipsed) in the 585th year before the first year of CHRIST, which was a leap-year, fell in the latter end of the third year of the 48th *Olympiad*; and the fourth year of that *Olympiad* began at the Summer Solstice following: but perhaps Mr. SMITH begins the years of the *Olympiad* from *January*, in order to make them correspond more readily with *Julian* years; and so reckons the month of *May*, when the Eclipse happened, to be in the fourth year of that *Olympiad*.

The Place or Longitude of the Sun at that time was ♉ 29° 43′ 17″, to which same place the Sun returned (after 2300 years, *viz.*) *A. D.* 1716, on *May*, 9d 5h 6m after noon: so that, with respect to the Sun's place, the 9th of *May*, 1716, answers to the 28th of *May* in the 585th year before the first year of CHRIST; that is, the Sun had the same Longitude on both those days.

"before

" before it past *Sardis* and the *Asiatic* towns, " where the predictor lived; because an invisible " Eclipse could have been of no service to demon- " strate his ability in Astronomical Sciences to his " countrymen, as it could give no proof of it's " reality.

324. " For a farther illustration, THUCYDIDES " relates, that a solar Eclipse happened on a Sum- " mer's day in the afternoon, in the first year of " the *Peloponnesian* war, so great, that the Stars ap- " peared. RHODIUS was victor in the *Olympic* " games the fourth year of the said war, being also " the fourth of the 87th *Olympiad*, on the 428th " year before CHRIST. So that the Eclipse must " have happened in the 431st year before CHRIST; " and by computation it appears, that on the 3d " of *August* there was a signal Eclipse which would " have past over *Athens*, central about 6 in the " evening, but which our present Tables bring no " farther than the antient *Syrtes* on the *African* " coast, above 400 miles from *Athens*; which " suffering in that case but 9 Digits, could by no " means exhibit the remarkable darkness recited " by this historian; the center therefore seems to " have past *Athens* about 6 in the evening, and " probably might go down about *Jerusalem*, or " near it, contrary to the construction of the pre- " sent Tables. I have only obviated these things " by way of caution to the present Astronomers, " in re-computing antient Eclipses; and refer them " to examine the Eclipse of *Nicias*, so fatal to the " *Athenian* fleet*; that which overthrew the *Mace-* " *donian* Army †, &c." So far Mr. SMITH.

THUCYDIDES'S Eclipse.

325. In any year, the number of Eclipses of both Luminaries cannot be less than two, nor more than seven; the most usual number is four, and it is very rare to have more than six. For the Sun passes by both the Nodes but once a year, unless

The number of Eclipses.

* Before CHRIST 413, *August* 27.
† Before CHRIST 168, *June* 21.

he

he passes by one of them in the beginning of the year; and if he does, he will pass by the same Node again a little before the year be finished; because, as these points move 19⅓ degrees backward every year, the Sun will come to either of them 173 days after the other, § 319. And when either Node is within 17 degrees of the Sun at the time of New Moon, the Sun will be eclipsed. At the subsequent opposition, the Moon will be eclipsed in the other Node; and come round to the next conjunction again ere the former Node be 17 degrees past the Sun, and will therefore eclipse him again. When three Eclipses fall about either Node, the like number generally falls about the opposite; as the Sun comes to it in 173 days afterwards: and six Lunations contain but four days more. Thus, there may be two Eclipses of the Sun and one of the Moon about each of her Nodes. But when the Moon changes in either of the Nodes, she cannot be near enough the other Node at the next Full to be eclipsed; and in six lunar months afterward she will change near the other Node: in these cases there can be but two Eclipses in a year, and they are both of the Sun.

326. A longer period than the above-mentioned, § 320, for comparing and examining Eclipses which happen at long intervals of time, is 557 years 21 days 18 hours 30 minutes 11 seconds; in which time there are 6890 mean Lunations; and the Sun and Node meet again so nearly as to be but 11 seconds distant: but then it is not the same Eclipse that returns, as in the shorter period above-mentioned.

327. We shall subjoin a Catalogue of Eclipses recorded in history, from 721 years before CHRIST to *A. D.* 1485; of computed Eclipses from 1485 to 1700; and of all the Eclipses visible in *Europe* from 1700 to 1800. From the beginning of the Catalogue to *A D.* 1485 the Eclipses are taken from STRUYK's *Introduction to universal Geography*, as

as that indefatigable author has, with much labour, collected them from *Ptolemy*, *Thucydides*, *Plutarch*, *Calvisius*, *Xenophon*, *Diodorus Siculus*, *Justin*, *Polybius*, *Titus Livius*, *Cicero*, *Lucanus*, *Theophanes*, *Dion. Cassius*, and many others. From 1485 to 1700 the Eclipses are taken from *Ricciolus's Almagest*: and from 1700 to 1800 from *L'Art de verifier les Dates*. Those from *Struyk* have all the places mentioned where they were observed: Those from the *French* authors, *viz.* the religious *Benedictines* of the Congregation of *St. Maur*, are fitted to the Meridian of *Paris*: And concerning those from *Ricciolus*, that author gives the following account.

An account of the following Catalogue of Eclipses.

"Because it is of great use for fixing the Cycles or Revolutions of Eclipses, to have at hand, without the trouble of calculation, a list of successive Eclipses for many years, computed by authors of *Ephemerides*, although from Tables not perfect in all respects, I shall for the benefit of Astronomers give a summary collection of such. The authors I extract from are, an anonymous one who published *Ephemerides* from 1484 to 1506 inclusive: *Jacobus Pilaumen* and *Jo. Stæflerinus*, to the Meridian of *Ulm*, from 1507 to 1534: *Lucas Gauricus*, to the Latitude of 45 degrees, from 1534 to 1551: *Peter Appian*, to the Meridian of *Leysing*, from 1538 to 1578: *Jo. Stæflerus*, to the Meridian of *Tubing*, from 1543 to 1554: *Petrus Pitatus*, to the Meridian of *Venice*, from 1544 to 1556: *Georgius-Joachimus Rheticus*, for the year 1551: *Nicholaus Simus*, to the Meridian of *Bologna*, from 1552 to 1568: *Michael Mæstlin*, to the Meridian of *Tubing*, from 1557 to 1590: *Jo. Stadius*, to the Meridian of *Antwerp*, from 1554 to 1574: *Jo. Antoninus Maginus*, to the Meridian of *Venice*, from 1581 to 1630: *David Origan*, to the Meridian of *Franckfort* on the *Oder*, from 1595 to 1664: *Andrew Argol*, to the Meridian of *Rome*, from 1630 to 1700: *Franciscus Montebrunus*, to the Meridian of *Bologna*, from 1461 to 1660: Among which, *Stadius*, *Mæstlin*, and *Maginus*,

ginus, uſed the *Prutenic* Tables; *Origan* the *Prutenic* and *Tychonic*; *Montebrunus* the *Lanſbergian*, as likewiſe thoſe of *Duret*. Almoſt all the reſt the *Alphonſine*.

But, that the places may readily be known for which theſe Eclipſes were computed, and from what Tables, conſult the following Liſt, in which the years *incluſive* are alſo ſet down.

From	To	
1485	1506	The place and author unknown.
1507	1553	*Ulm* in *Suabia*, from the *Alphonſine*.
1554	1576	*Antwerp*, from the *Prutenic*.
1577	1585	*Tubing*, from the *Prutenic*.
1586	1594	*Venice*, from the *Prutenic*.
1595	1600	*Franckfort* on the *Oder*, from the *Prutenic*.
1601	1640	*Franckfort* on the *Oder*, from the *Tychonic*.
1641	1660	*Bologna*, from the *Lanſbergian*.
1661	1700	*Rome*, from the *Tychonic*."

So far Ricciolus.

N. B. The Eclipſes marked with an Aſteriſk are not in Ricciolus's Catalogue, but are ſupplied from *L'Art de verifier les Dates*.

From the beginning of the Catalogue to *A. D.* 1700, the time is reckoned from the noon of the day mentioned to the noon of the following day: but from 1700 to 1800 the time is ſet down according to our common way of reckoning. Thoſe marked *Pekin* and *Canton* are Eclipſes from the *Chineſe* chronology according to Struyk; and throughout the Table this mark ☉ ſignifies *Sun*, and this ☽ *Moon*.

Struyk's

STRUYK's Catalogue of ECLIPSES.

Bef. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
721	Babylon	☽	Mar.	19	10	34	Total	
720	Babylon	☽	Mar.	8	11	56	1	5
720	Babylon	☽	Sept.	1	10	18	5	4
621	Babylon	☽	Apr.	21	18	22	2	36
523	Babylon	☽	July	16	12	47	7	24
502	Babylon	☽	Nov.	19	12	21	1	52
491	Babylon	☽	Apr.	25	12	12	1	44
431	Athens	☉	Aug.	3	6	35	11	0
425	Athens	☽	Oct.	9	6	45	Total	
424	Athens	☉	Mar.	20	20	17	9	0
413	Athens	☽	Aug.	27	10	15	Total	
406	Athens	☽	Apr.	15	8	50	Total	
404	Athens	☉	Sept.	2	21	12	8	40
403	Pekin	☉	Aug.	28	5	53	10	40
394	Gnide	☉	Aug.	13	22	17	11	0
383	Athens	☽	Dec.	22	19	6	2	1
382	Athens	☽	June	18	8	54	6	15
382	Athens	☽	Dec.	12	10	21	Total	
364	Thebes	☉	July	12	23	51	6	10
357	Syracuse	☉	Feb.	28	22	—	3	33
357	Zant	☽	Aug.	29	7	29	4	21
340	Zant	☉	Sept.	14	18	—	9	0
331	Arbela	☽	Sept.	20	10	9	Total	
310	Sicily Island	☉	Aug.	14	20	5	10	22
219	Mysia	☽	Mar.	19	14	5	Total	
218	Pergamos	☽	Sept.	1	rising		Total	
217	Sardinia	☉	Feb.	11	1	57	9	6
203	Frusini	☉	May	6	2	52	5	40
202	Cumis	☉	Oct.	18	22	24	1	0
201	Athens	☽	Sept.	22	7	14	8	58
200	Athens	☽	Mar.	19	13	9	Total	
200	Athens	☽	Sept.	11	14	48	Total	
198	Rome	☉	Aug.	6	—		—	
190	Rome	☉	Mar.	13	18	—	11	0
188	Rome	☉	July	16	20	38	10	48
174	Athens	☽	Apr.	30	14	33	7	1
168	Macedonia	☽	June	21	8	2	Total	
141	Rhodes	☽	Jan.	27	10	8	3	26
104	Rome	☉	July	18	22	0	11	52
63	Rome	☽	Oct.	27	6	22	Total	
60	Gibraltar	☉	Mar.	16	setting		Central	
54	Canton	☉	May	9	3	41	Total	
51	Rome	☉	Mar.	7	2	12	9	0
48	Rome	☽	Jan.	18	10	0	Total	
45	Rome	☽	Nov.	6	14	—	Total	
36	Rome	☉	May	19	3	52	6	47

Struyk's Catalogue of ECLIPSES.

Bef. Chr.	Eclipſes of the Sun and Moon ſeen at		M. & D.		Middle H.	M.	Digits eclipſed	
31	Rome	☉	Aug.	20	ſetting		Gr. Ecl.	
29	Canton	☉	Jan.	5	4	2	11	0
28	Pekin	☉	June	18	23	48	Total	
26	Canton	☉	Oct.	23	4	16	11	15
24	Pekin	☉	April	7	4	11	2	0
16	Pekin	☉	Nov.	1	5	13	2	8
2	Canton	☉	Feb.	1	20	8	11	42
Aft. Chr.								
1	Pekin	☉	June	10	1	10	11	43
5	Rome	☉	Mar.	28	4	13	4	45
14	Panonia	☽	Sept.	26	17	15	Total	
27	Canton	☉	July	22	8	56	Total	
30	Canton	☉	Nov.	13	19	20	10	30
40	Pekin	☉	Apr.	30	5	50	7	34
45	Rome	☉	July	31	22	1	5	17
46	Pekin	☉	July	21	22	25	2	10
46	Rome	☽	Dec.	31	9	52	Total	
49	Pekin	☉	May	20	7	16	10	8
53	Canton	☉	Mar.	8	20	42	11	6
55	Pekin	☉	July	12	21	50	6	40
56	Canton	☉	Dec.	25	0	28	9	20
59	Rome	☉	Apr.	30	3	8	10	38
60	Canton	☉	Oct.	13	3	31	10	30
65	Canton	☉	Dec.	15	21	50	10	23
69	Rome	☽	Oct.	18	10	43	10	49
70	Canton	☉	Sept.	22	21	13	8	26
71	Rome	☽	Mar.	4	8	32	6	0
95	Epheſus	☉	May	21	——		1	0
125	Alexandria	☽	April	5	9	16	1	44
133	Alexandria	☽	May	6	11	44	Total	
134	Alexandria	☽	Oct.	20	11	5	10	19
136	Alexandria	☽	March	5	15	56	5	17
237	Bologna	☉	April	12	——		Total	
238	Rome	☉	April	1	20	20	8	45
290	Carthage	☉	May	15	3	20	11	20
304	Rome	☽	Aug.	31	9	36	Total	
316	Conſtantinople	☉	Dec.	30	19	53	2	18
334	Toledo	☉	July	17	at noon		Central	
348	Conſtantinople	☉	Oct.	8	19	24	8	0
360	Iſpahan	☉	Aug.	27	18	0	Central	
364	Alexandria	☽	Nov.	25	15	24	Total	
401	Rome	☽	June	11	——		Total	
401	Rome	☽	Dec.	6	12	15	Total	
402	Rome	☽	June	1	8	43	10	2

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipſes of the Sun and Moon ſeen at		M. & D.		Middle H.	M.	Digits eclipſed	
402	Rome	☉	Nov.	10	20	33	10	30
447	Compoſtello	☉	Dec.	23	0	46	1	—
451	Compoſtello	☽	April	1	16	34	19	52
451	Compoſtello	☽	Sept.	26	6	30	0	2
458	Chaves	☉	May	27	23	16	18	53
462	Compoſtello	☽	March	1	13	2	11	11
464	Chaves	☉	July	19	19	1	10	15
484	Conſtantinople	☉	Jan.	13	19	53	10	0
486	Conſtantinople	☉	May	19	1	10	5	15
497	Conſtantinople	☉	April	18	6	5	17	57
512	Conſtantinople	☉	June	28	23	8	1	50
538	England	☉	Feb.	14	19	—	8	23
540	London	☉	June	19	20	15	8	—
577	Tours	☽	Dec.	10	17	28	6	46
581	Paris	☽	April	4	13	33	6	42
582	Paris	☽	Sept.	17	12	41	Total	
590	Paris	☽	Oct.	18	6	30	9	25
592	Conſtantinople	☉	March	18	22	6	10	0
603	Paris	☉	Aug.	12	3	3	11	20
622	Conſtantinople	☽	Feb.	1	11	28	Total	
644	Paris	☉	Nov.	5	0	30	9	53
680	Paris	☽	June	17	12	30	Total	
683	Paris	☽	April	16	11	30	Total	
693	Conſtantinople	☉	Oct.	4	23	54	11	54
716	Conſtantinople	☽	Jan.	13	7	—	Total	
718	Conſtantinople	☉	June	3	1	15	Total	
733	England	☉	Aug.	13	20	—	11	1
734	England	☽	Jan.	23	14	—	Total	
752	England	☽	July	30	13	—	Total	
753	England	☉	June	8	22	—	10	35
753	England	☽	Jan.	23	13	—	Total	
760	England	☉	Aug.	15	4	—	8	15
760	London	☽	Aug.	30	5	50	10	40
764	England	☉	June	4	at noon		7	15
770	London	☽	Feb.	14	7	12	Total	
774	Rome	☽	Nov.	22	14	37	11	58
784	London	☽	Nov.	1	14	2	Total	
787	Conſtantinople	☉	Sept.	14	20	43	9	47
796	Conſtantinople	☽	March	27	16	22	Total	
800	Rome	☽	Jan.	15	9	0	10	17
807	Angouleſme	☉	Feb.	10	21	24	9	42
807	Paris	☽	Feb.	25	13	43	Total	
807	Paris	☽	Aug.	21	10	20	Total	
809	Paris	☉	July	15	21	33	8	8
809	Paris	☽	Dec.	25	8	—	Total	
810	Paris	☽	June	20	8	—	Total	

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.		Middle H.	M.	Digits eclipsed	
810	Paris	☉	Nov.	30	0	12	Total	
81c	Paris	☽	Dec.	14	8	—	Total	
812	Constantinople	☉	May	14	2	13	9	—
813	Cappadocia	☉	May	3	17	5	10	35
817	Paris	☽	Feb.	5	5	42	Total	
818	Paris	☉	July	6	18	—	6	35
820	Paris	☽	Nov.	23	6	26	Total	
824	Paris	☽	March	18	7	55	Total	
828	Paris	☽	June	30	15	—	Total	
828	Paris	☽	Dec.	24	13	45	Total	
831	Paris	☽	April	30	6	19	11	8
831	Paris	☉	May	15	23	—	4	24
831	Paris	☽	Oct.	24	11	18	Total	
832	Fulda	☽	April	18	9	0	Total	
840	Paris	☉	May	4	23	22	9	20
841	Paris	☉	Oct.	17	18	58	5	24
842	Paris	☽	March	29	14	38	Total	
843	Paris	☽	March	19	7	1	Total	
861	Paris	☽	March	29	15	7	Total	
878	Paris	☽	Oct.	14	16	—	Total	
878	Paris	☉	Oct.	29	1	—	11	14
883	Arracta	☽	July	23	7	44	11	—
889	Constantinople	☉	April	3	17	52	9	23
891	Constantinople	☉	Aug.	7	23	48	10	30
901	Arracta	☽	Aug.	2	15	7	Total	
904	London	☽	May	31	11	47	Total	
904	London	☽	Nov.	25	9	0	Total	
912	London	☽	Jan.	6	15	12	Total	
925	Paris	☽	March	31	15	17	Total	
934	Paris	☉	April	16	4	30	11	36
939	Paris	☉	July	18	19	45	10	7
955	Paris	☽	Sept.	4	11	18	Total	
961	Rhemes	☉	May	16	20	13	9	18
970	Constantinople	☉	May	7	18	38	11	22
976	London	☽	July	13	15	7	Total	
985	Messina	☉	July	20	3	52	4	10
989	Constantinople	☉	May	28	6	54	8	40
990	Fulda	☽	April	12	10	22	9	5
990	Fulda	☽	Oct.	6	15	4	11	10
990	Constantinople	☉	Oct.	21	0	45	10	5
995	Augsburgh	☽	July	14	11	27	Total	
1009	Ferrara	☽	Oct.	6	11	38	Total	
1010	Messina	☉	March	18	5	41	9	12
1016	Nimeguen	☽	Nov.	16	16	39	Total	
1017	Nimeguen	☉	Oct.	22	2	8	6	—
1020	Cologne	☽	Sept.	4	11	38	Total	

STRUYK's

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipſes of the Sun and Moon ſeen at		M. & D.	Middle H.	M.	Digits eclipſed
1023	London	☉	Jan. 23	23	29	11 —
1030	Rome	☽	Feb. 20	11	43	Total
1031	Paris	☽	Feb. 9	11	51	Total
1033	Paris	☽	Dec. 8	11	11	9 17
1034	Milan	☽	June 4	9	8	Total
1037	Paris	☉	April 17	20	45	10 45
1039	Auxerre	☉	Aug. 21	23	40	11 5
1042	Rome	☽	Jan. 8	16	39	Total
1044	Auxerre	☽	Nov. 7	16	12	10 1
1044	Cluny	☉	Nov. 21	22	12	11 —
1056	Nuremburg	☽	April 2	12	9	Total
1063	Rome	☽	Nov. 8	12	16	Total
1074	Augſburgh	☽	Oct. 7	10	13	Total
1080	Conſtantinople	☽	Nov. 29	11	12	9 36
1082	London	☽	May 14	10	32	10 2
1086	Conſtantinople	☉	Feb. 16	4	7	Total
1089	Naples	☽	June 25	6	6	Total
1093	Augſburgh	☉	Sept. 22	22	35	10 12
1096	Gembluors	☽	Feb. 10	16	4	Total
1096	Augſburgh	☽	Aug. 6	8	21	Total
1098	Augſburgh	☉	Dec. 25	1	25	10 12
1099	Naples	☽	Nov. 30	4	58	Total
1103	Rome	☽	Sept. 17	10	18	Total
1106	Erfurd	☽	July 17	11	28	11 54
1107	Naples	☽	Jan. 10	13	16	Total
1109	Erfurd	☉	May 31	1	30	10 20
1110	London	☽	May 5	10	51	Total
1113	Jeruſalem	☉	Mar. 18	19	0	9 12
1114	London	☽	Aug. 17	15	5	Total
1117	Trier	☽	June 15	13	26	Total
1117	Trier	☽	Dec. 10	12	51	Total
1118	Naples	☽	Nov. 29	15	46	4 11
1121	Triers	☽	Sept. 27	16	47	Total
1122	Prague	☽	March 24	11	20	3 49
1124	Erfurd	☽	Feb. 1	6	43	8 39
1124	London	☉	Auguſt 10	23	29	9 58
1132	Erfurd	☽	March 3	8	14	Total
1133	Prague	☽	Feb. 20	16	41	3 23
1135	London	☽	Dec. 22	20	11	Total
1142	Rome	☽	Feb. 11	14	17	8 30
1143	Rome	☽	Feb. 1	6	36	Total
1147	Auranches	☉	Oct. 25	22	38	7 20
1149	Bary	☽	March 25	13	54	5 29
1151	Eimbeck	☽	Auguſt 28	12	4	4 29
1153	Augſburgh	☉	Jan. 26	0	42	11 —
1154	Paris	☽	June 26	16	1	Total

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipfes of the Sun and Moon feen at		M. & D.		Middle H.	M.	Digits eclipfed	
1154	Paris	☽	Dec.	21	8	30	4	42
1155	Auranches	☽	June	16	8	45	0	53
1160	Rome	☽	Auguft	18	7	53	6	49
1161	Rome	☽	Auguft	7	8	15	Total	
1162	Erfurd	☽	Feb.	1	6	40	5	56
1162	Erfurd	☽	July	27	12	30	4	11
1163	Mont Caffin.	☉	July	3	7	40	2	0
1164	Milan	☽	June	6	10	0	Total	
1168	London	☽	Sept.	18	14	0	Total	
1172	Cologne	☽	Jan.	11	13	31	Total	
1176	Auranches	☽	April	25	7	2	8	6
1176	Auranches	☽	Oct.	19	11	20	8	53
1178	Cologne	☽	March	5	fetting		7	52
1178	Auranches	☽	Auguft	29	13	52	5	31
1178	Cologne	☉	Sept.	12	—	—	10	51
1179	Cologne	☽	Auguft	18	14	28	Total	
1180	Auranches	☉	Jan.	28	4	14	10	34
1181	Auranches	☉	July	13	3	15	3	48
1181	Auranches	☽	Dec.	22	8	58	4	40
1185	Rhemes	☉	May	1	1	53	9	0
1186	Cologne	☽	April	5	6	—	Total	
1186	Franckfort	☉	April	20	7	19	4	0
1187	Paris	☽	March	25	16	17	8	42
1187	England	☉	Sept.	3	21	54	8	6
1189	England	☽	Feb.	2	10	—	9	—
1191	England	☉	June	23	0	20	11	32
1192	France	☽	Nov.	20	14	—	6	—
1193	France	☽	Nov.	10	5	27	Total	
1194	London	☉	April	22	2	15	6	49
1200	London	☽	Jan.	2	17	2	4	35
1201	London	☽	June	17	15	4	Total	
1204	England	☽	April	15	12	39	Total	
1204	Saltzburg	☽	Oct.	10	6	32	Total	
1207	Rhemes	☉	Feb.	27	10	50	10	20
1208	Rhemes	☽	Feb.	2	5	10	Total	
1211	Vienna	☽	Nov.	21	13	57	Total	
1215	Cologne	☽	March	16	15	35	Total	
121	Acre	☉	Feb.	18	21	15	11	36
1216	Acre	☽	March	5	9	38	7	4
1218	Damiétta	☽	July	9	9	46	11	31
1222	Rome	☽	Oct.	22	14	28	Total	
1223	Colmar	☽	April	16	8	13	11	0
1228	Naples	☉	Dec.	27	9	55	9	19
1230	Naples	☉	May	13	17	—	Total	
1230	London	☽	Nov.	21	13	21	9	34
1232	Rhemes	☉	Oct.	15	4	29	4	25

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipſes of the Sun and Moon ſeen at		M. & D.		Middle H.	M.	Digits eclipſed	
124[illegible]	Rhemes	☉	July	24	17	47	6	—
1248	London	☽	June	7	8	49	Total	
1255	London	☽	July	20	9	47	Total	
1255	Conſtantinople	☉	Dec.	30	2	52	Annul.	
1258	Augſburgh	☽	May	18	11	17	Total	
1261	Vienna	☉	March	31	22	40	9	8
1262	Vienna	☽	March	7	5	50	Total	
1262	Vienna	☽	Auguſt	30	14	39	Total	
1263	Vienna	☽	Feb.	24	6	52	6	29
1263	Augſburgh	☉	Auguſt	5	3	24	11	17
1263	Vienna	☽	Auguſt	20	7	35	9	7
1265	Vienna	☽	Dec.	23	16	25	Total	
1267	Conſtantinople	☉	May	24	23	11	11	40
1270	Vienna	☉	March	22	18	47	10	40
1272	Vienna	☽	Auguſt	10	7	27	8	53
1274	Vienna	☽	Jan.	23	10	39	9	25
1275	Lauben	☽	Dec.	4	6	20	4	29
1276	Vienna	☽	Nov.	22	15	—	Total	
1277	Vienna	☽	May	18	—	—	Total	
1279	Franckfort	☉	April	12	6	55	10	6
1280	London	☽	March	17	12	12	Total	
1284	Reggio	☽	Dec.	23	16	11	9	13
1290	Wittemburg	☉	Sept.	4	19	37	10	30
1291	London	☽	Feb.	14	10	2	Total	
1302	Conſtantinople	☽	Jan.	14	10	25	Total	
1307	Ferrara	☉	April	2	22	18	0	54
1309	London	☽	Feb.	24	17	44	Total	
1309	Lucca	☽	Auguſt	21	10	32	Total	
1310	Wittemburg	☉	Jan.	31	2	2	10	10
1310	Torcello	☽	Feb.	14	4	8	10	20
1310	Torcello	☽	Auguſt	10	15	33	7	16
1312	Wittemburg	☉	July	4	19	49	3	23
1312	Plaiſance	☽	Dec.	14	7	19	Total	
1313	Torcello	☽	Dec.	3	8	58	9	34
1316	Modena	☽	Oct.	1	14	55	Total	
1321	Wittemburg	☉	June	25	18	1	11	17
1323	Florence	☽	May	20	15	24	Total	
1324	Florence	☽	May	9	6	3	Total	
1324	Wittemburg	☉	April	23	6	35	8	8
1327	Conſtantinople	☽	Auguſt	31	18	26	Total	
1328	Conſtantinople	☽	Feb.	25	13	47	11	—
1330	Florence	☽	June	30	15	10	7	34
1330	Conſtantinople	☉	July	16	4	5	10	43
1330	Prague	☽	Dec.	25	15	49	Total	
1331	Prague	☉	Nov.	29	20	26	7	41
1331	Prague	☽	Dec.	14	18	—	11	—

STRUYK's Catalogue of ECLIPSES.

Aft. Chr.	Eclipses of the Sun and Moon seen at		M. & D.	Middle H.	M.	Digits eclipsed
1333	Wittemburg	☉	May 14	3	—	10 18
1334	Cesena	☽	April 19	10	33	Total
1341	Constantinople	☽	Nov. 23	12	23	Total
1341	Constantinople	☉	Dec. 8	22	15	6 30
1342	Constantinople	☽	May 20	14	27	Total
1344	Alexandria	☉	Oct. 6	18	40	8 55
1349	Wittemburg	☽	June 30	12	20	Total
1354	Wittemburg	☉	Sept. 16	20	45	8 43
1356	Florence	☽	Feb. 16	11	43	Total
1361	Constantinople	☉	May 4	22	15	8 54
1357	Sienna	☽	Jan. 16	8	27	Total
1389	Eugibio	☽	Nov. 3	17	5	Total
1396	Augsburg	☉	Jan. 11	0	16	6 22
1396	Augsburg	☽	June 21	11	10	Total
1399	Forli	☉	Oct. 29	0	43	9 —
1406	Constantinople	☽	June 1	13	—	10 31
1406	Constantinople	☉	June 15	18	1	11 38
1408	Forli	☉	Oct. 18	21	47	9 32
1409	Constantinople	☉	April 15	3	1	10 48
1410	Vienna	☽	March 20	13	13	Total
1415	Wittemburg	☉	June 6	6	43	Total
1419	Franckfort	☉	March 25	22	5	1 45
1421	Forli	☽	Feb. 17	8	2	Total
1422	Forli	☽	Feb. 6	8	26	11 7
1424	Wittemburg	☉	June 26	3	57	11 20
1431	Forli	☉	Feb. 12	2	4	1 39
1433	Wittemburg	☉	June 17	5	—	Total
1438	Wittemburg	☉	Sept. 18	20	59	8 7
1442	Rome	☽	Dec. 17	3	56	Total
1448	Tubing	☉	August 28	22	23	8 53
1450	Constantinople	☽	July 24	7	19	Total
1457	Vienna	☽	Sept. 3	11	17	Total
1460	Austria	☽	July 3	7	31	5 23
1460	Austria	☉	July 17	17	32	11 19
1460	Vienna	☽	Dec. 27	13	30	Total
1461	Vienna	☽	June 22	11	50	Total
1461	Rome	☽	Dec. 17	—	—	Total
1462	Viterbo	☽	June 11	15	—	7 38
1462	Viterbo	☉	Nov. 21	0	10	2 6
1464	Padua	☽	April 21	12	43	Total
1465	Rome	☉	Sept. 20	5	15	8 46
1465	Rome	☽	Oct. 4	5	12	Total
1469	Rome	☽	Jan. 27	7	9	Total
1485	Norimburg	☉	March 1	3	53	11 —

All

All the following ECLIPSES are taken from RICCIOLUS, except those marked with an Asterisk, which are from *L'Art de verifier les Dates.*

Aft. Chr.		M.&D.	Middle H.	M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H.	M.	Digits eclipsed
1486	☽	Feb. 18	5	41	Total	1508	☉	May 29	6	—	*
1486	☉	Mar. 5	17	43	9 0	1508	☽	June 12	17	40	Total
1487	☽	Feb. 7	15	49	Total	1509	☽	June 2	11	11	7 0
1487	☉	July 20	2	6	7 0	1509	☉	Nov. 11	22	—	*
1488	☽	Jan. 28	6	—	*	1510	☽	Oct. 16	19	—	*
1488	☉	July 8	17	30	4 0	1511	☽	Oct. 6	11	50	Total
1489	☽	Dec. 7	17	41	Total	1512	☽	Sept. 25	3	56	Total
1490	☉	May 19	Noon		*	1513	☉	Mar. 7	0	30	6 0
1490	☽	June 2	10	6	Total	1513	☉	July 30	1	—	*
1490	☽	Nov. 26	18	25	Total	1515	☽	Jan. 29	15	18	Total
1491	☉	Mar. 8	2	19	9	1516	☽	Jan. 19	6	0	Total
1491	☽	Nov. 15	18	—	*	1516	☽	July 13	11	37	Total
1492	☉	Apr. 26	7	—	*	1516	☉	Dec. 23	3	47	3 0
1492	☉	Oct. 20	23	—	*	1517	☉	June 18	16	—	*
1493	☽	April 1	14	0	Total	1517	☽	Nov. 27	19	—	*
1493	☉	Oct. 10	2	40	8 0	1518	☽	May 24	11	19	9 11
1494	☉	Mar. 7	4	12	4 0	1518	☉	June 7	17	56	11 0
1494	☽	Mar. 21	14	38	Total	1519	☉	May 28	1	—	*
1494	☽	Sept. 14	19	45	Total	1519	☉	Oct. 23	4	33	6 0
1495	☽	Mar. 10	16	—	*	1519	☽	Nov. 6	6	24	Total
1495	☉	Aug. 19	17	—	*	1520	☽	May 2	7	—	*
1496	☽	Jan. 29	14	—	*	1520	☉	Oct. 11	5	22	3
1497	☽	Jan. 18	6	38	Total	1520	☽	Oct. 25	19	—	*
1497	☉	July 29	3	2	3 0	1520	☽	Mar. 21	17	—	*
1499	☽	June 22	17	—	*	1521	☉	April 6	19	—	*
1499	☉	Aug. 23	18	—	*	1521	☉	Sept. 30	3	—	*
1499	☽	Nov. 17	10	—	*	1522	☽	Sept. 5	12	17	Total
1500	☉	Mar. 27		In the	Night	1523	☽	Mar. 1	8	26	Total
1500	☽	Apr. 11		At	Noon	1523	☽	Aug 25	15	24	Total
1500	☽	Oct. 5	14	2	10 0	1524	☉	Feb. 4	1	—	*
1501	☽	May 2	17	49	Total	1524	☽	Aug. 16	16	—	*
1502	☉	Sept. 30	19	45	10 0	1525	☉	Jan. 23	4	—	*
1502	☽	Oct. 15	12	20	2 0	1525	☽	July 4	10	10	Total
1503	☽	Mar. 12	9	—	*	1525	☽	Dec. 29	10	46	Total
1503	☉	Sept. 19	22	—	*	1526	☽	Dec. 18	10	30	Total
1504	☽	Feb. 29	13	36	Total	1527	☉	Jan. 2	3	—	*
1504	☉	Mar. 16	3	—	*	1527	☽	Dec 7	10	—	*
1505	☽	Aug. 14	8	18	Total	1528	☉	May 17	20	—	*
1506	☽	Feb. 7	15	—	*	1529	☽	Oct. 16	20	23	11 55
1507	☉	July 20	3	11	2 0	1530	☉	Mar. 28	18	23	8 24
1506	☽	Aug. 3	10	—	*	1530	☽	Oct. 6	12	11	Total
1507	☉	Jan. 12	19	—	*	1531	☽	April 1	7	—	*
1508	☉	Jan. 2	4	—	*	1532	☉	Aug. 30	0	49	3 35

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RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1533	☽	Aug. 4	11 50	Total	1556	☉	Nov. 1	18 0	9 41
1533	☉	Aug. 19	17 —	*	1556	☽	Nov. 16	12 44	6 55
1534	☉	Jan. 14	1 42	5 45	1557	☉	Oct. 20	20 —	*
1534	☽	Jan. 29	14 25	Total	1558	☽	April 2	11 0	9 50
1535	☉	June 30	Noon	*	1558	☉	Apr. 18	1 —	*
1535	☽	July 14	8 —	*	1559	☽	Apr. 16	4 50	Total
1535	☉	Dec. 24	2 —	*	1560	☽	Mar. 11	15 40	4 13
1536	☉	June 18	2 2	8 0	1560	☉	Aug. 21	1 0	6 22
1536	☽	Nov. 27	6 21	10 15	1560	☽	Sept. 4	7 —	*
1537	☽	May 24	8 3	Total	1561	☉	Feb. 13	19 —	*
1537	☉	June 7	8 —	*	1562	☉	Feb. 3	5 —	*
1537	☽	Nov. 16	14 56	Total	1562	☽	July 15	15 50	Total
1538	☽	May 13	14 24	3 0	1563	☉	Jan. 22	19 —	*
1538	☽	Nov. 6	5 31	3 37	1563	☉	June 20	4 50	8 38
1539	☉	April 8	4 33	9 0	1563	☽	July 5	8 4	11 34
1540	☉	April 6	17 15	Total	1565	☉	Mar. 7	12 53	——
1541	☽	Mar. 11	16 34	Total	1565	☽	May 14	16 —	*
1541	☉	Aug. 21	0 56	3	1565	☽	Nov. 7	12 46	11 46
1542	☽	Mar. 1	8 46	1 38	1566	☽	Oct. 28	5 38	Total
1542	☉	Aug. 10	17 —	*	1567	☉	April 8	23 4	9 34
1543	☽	July 15	16 —	*	1567	☽	Oct. 17	13 43	2 40
1544	☽	Jan. 9	18 13	Total	1568	☉	Mar. 28	5 —	*
1544	☉	Jan. 23	21 16	11 17	1569	☽	Mar. 2	15 18	Total
1544	☽	July 4	8 31	Total	1570	☽	Feb. 20	5 46	Total
1544	☽	Dec. 28	18 27	Total	1570	☽	Aug. 15	9 17	Total
1545	☉	June 8	20 48	3 45	1571	☉	Jan. 25	4 —	*
1545	☽	Dec. 17	18 —	*	1572	☉	Jan. 14	19 —	*
1546	☉	May 30	5 —	*	1572	☽	June 25	9 0	5 26
1546	☉	Nov. 22	23 —	*	1573	☉	June 28	18 —	*
1547	☽	May 4	10 27	8 0	1573	☉	Nov. 24	4 —	*
1547	☽	Oct. 28	4 56	11 34	1573	☽	Dec. 8	6 51	Total
1547	☉	Nov. 12	2 9	9 30	1574	☉	Nov. 13	3 50	5 21
1548	☉	April 8	3 —	*	1575	☉	May 19	8 —	*
1548	☽	Apr. 22	11 24	Total	1575	☉	Nov. 2	5 —	*
1549	☽	Apr. 11	15 19	2 0	1576	☽	Oct. 7	9 45	——
1549	☽	Oct. 6	6 —	*	1577	☽	April 2	8 33	Total
1550	☉	Mar. 16	20 —	*	1577	☽	Sept. 26	13 4	Total
1551	☽	Feb. 20	8 21	Total	1578	☽	Sept. 15	13 4	2 20
1551	☉	Aug. 31	2 0	1 52	1579	☉	Feb. 15	5 41	8 36
1553	☉	Jan. 12	22 54	1 22	1579	☉	Aug. 20	19 0	*
1553	☉	July 10	7 —	*	1580	☽	Jan. 31	10 7	Total
1553	☽	July 24	16 0	0 31	1581	☽	Jan. 19	9 22	Total
1554	☉	June 29	6 —	*	1581	☽	July 15	17 51	Total
1554	☽	Dec. 8	13 7	10 12	1582	☽	Jan. 8	10 29	0 53
1555	☽	June 4	15 0	Total	1582	☉	June 9	17 5	7 5
1555	☉	Nov. 13	19 —	*	1583	☽	Nov. 25	21 51	Total

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1584	☉	May 9	18 20	3 36	1601	☽	June 15	6 18	4 52
1584	☽	Nov. 17	14 15	Total	1601	☉	June 29	China	4 29
1585	☉	Apr. 29	7 53	11 7	1601	☽	Dec. 9	7 6	10 53
1585	☽	May 13	5 9	6 54	1601	☉	Dec. 24	2 46	9 52
1586	☽	Sept. 27	8 —	*	1602	☉	May 21	Greenl.	2 41
1586	☉	Oct. 12	Noon	*	1602	☽	June 4	7 18	Total
1587	☽	Sept. 16	9 28	10 2	1602	☉	June 19	N.Gra.	5 43
1588	☉	Feb. 26	1 23	1 3	1602	☉	Nov. 13	Magel.	3 —
1588	☽	Mar. 12	14 14	Total	1602	☽	Nov. 28	10 2	Total
1588	☽	Sept. 4	17 30	Total	1603	☉	May 10	China	11 21
1589	☉	Aug. 10	18 —	*	1603	☽	May 24	11 41	7 59
1589	☽	Aug. 25	8 1	3 54	1603	☉	Nov. 3	Rom. I.	11 17
1590	☉	Feb. 4	5 —	*	1603	☽	Nov. 18	7 31	3 26
1590	☽	July 16	17 4	3 54	1604	☉	Apr. 20	Arabia	9 32
1590	☉	July 30	19 57	10 27	1604	☉	Oct. 22	Peru	6 49
1591	☽	Jan. 9	6 21	9 40	1605	☽	April 3	9 19	11 49
1591	☽	July 6	5 8	Total	1605	☉	Apr. 18	Madag.	5 31
1591	☉	July 20	4 2	1 0	1605	☽	Sept. 27	4 27	9 26
1591	☽	Dec. 29	16 11	Total	1605	☉	Oct. 12	2 32	9 24
1592	☽	June 24	10 13	8 58	1606	☉	Mar. 8	Mexico	6 0
1592	☽	Dec. 18	7 24	5 54	1606	☽	Mar. 24	11 17	Total
1593	☉	May 30	2 30	2 38	1606	☉	Sept. 2	Magel.	6 40
1594	☉	May 19	14 58	10 23	1606	☉	Sept. 2	Magel.	6 40
1594	☽	Oct. 28	19 15	9 40	1606	☽	Sept. 16	15 6	Total
1595	☉	April 9	Ter. de	Fuego	1607	☉	Feb. 25	21 48	1 13
1595	☽	Apr. 24	4 12	Total	1607	☽	Mar. 13	6 36	1 22
1595	☉	May 7	22 —	*	1607	☉	Sept. 5	15 40	4 7
1595	☉	Oct. 3	2 4	5 18	1608	☉	Feb. 15	at the	Antipo
1595	☽	Oct. 18	20 47	Total	1608	☽	July 27	0 30	1 53
1596	☉	Mar. 28	In	Chili	1608	☉	Aug. 9	4 39	0 40
1596	☽	Apr. 12	8 52	6 4	1609	☽	Jan. 19	15 21	10 32
1596	☉	Sept. 21	In	China	1609	☉	Feb. 4	Fuego	5 22
1596	☽	Oct. 6	21 15	3 33	1609	☽	July 16	12 8	Total
1597	☉	Mar. 17	St. Pet.	Isle	1609	☉	July 30	Canada	4 10
1597	☉	Sept. 11	Picora	9 49	1609	☉	Dec. 26	19 —	5 50
1598	☽	Feb. 20	18 12	10 55	1610	☽	Jan. 9	1 31	Total
1598	☉	Mar. 6	22 12	11 57	1610	☉	June 20	Java	10 46
1598	☽	Aug. 16	8 15	Total	1610	☽	July 5	16 58	11 13
1598	☉	Aug. 31	Magel.	8 34	1610	☉	Dec. 15	Cyprus	4 50
1599	☽	Feb. 10	17 21	Total	1610	☽	Dec. 29	16 47	4 23
1599	☉	July 22	4 31	4 18	1611	☉	June 10	Califor.	11 30
1599	☽	Aug. 6	——	Total	1612	☽	May 14	10 38	7 22
1600	☉	Jan 15	Java	11 48	1612	☉	May 29	23 38	7 14
1600	☽	Jan. 30	6 40	2 58	1612	☽	Nov. 8	3 22	9 49
1600	☉	July 10	2 10	5 39	1612	☉	Nov. 22	Magel.	9 0
1601	☉	Jan 4	Ethiop.	0 50	1613	☉	Apr. 20	Magel	lanica

Ricciolus's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1613	☽	May 4	0 35	Total	1625	☉	Mar. 8	Florida	
1613	☉	May 19	East	Tartary	1625	☽	Mar. 23	14 11	2 11
1613	☉	Oct. 13	South	Amer.	1625	☉	Sept. 1	St. Pe	ter's Isl.
1613	☽	Oct. 28	4 19	Total	1625	☽	Sept. 16	11 41	5 6
1614	☉	April 8	N. Gui.	8 44	1626	☉	Feb. 25	Madag.	8 27
1614	☽	Apr. 23	17 36	5 25	1626	☽	Aug. 7	7 48	0 25
1614	☉	Oct. 3	0 57	5 2	1626	☉	Aug. 21	In	Mexico
1614	☽	Oct. 17	4 38	4 56	1627	☽	Jan. 30	11 38	10 21
1615	☉	Mar. 29	Goa	10 38	1627	☉	Feb. 15	Magel	lanica
1615	☉	Sept. 22	Salom	Isle	1627	☽	July 27	9 4	Total
1616	☽	Mar. 3	1 58	Total	1627	☉	Aug. 11	Tenduc	10 0
1616	☉	Mar. 17	Mexico	6 47	1628	☉	Jan. 6	Tenduc	5 40
1616	☽	Aug. 26	15 33	Total	1628	☽	Jan. 20	10 11	Total
1616	☽	Sept. 10	Magel	10 33	1628	☉	July 1	C Good	Hope
1617	☉	Feb. 5	Magel	lanica	1628	☽	July 16	11 26	Total
1617	☽	Feb. 20	1 49	Total	1628	☉	Dec. 25	In Eng	land
1617	☉	Mar. 6	22 —		1629	☽	Jan. 9	1 36	4 27
1617	☉	Aug. 1	Biarmia	*	1629	☉	June 11	Ganges	11 25
1617	☽	Aug. 16	8 22	Total	1629	☉	Dec. 14	Peru	10 14
1618	☉	Jan. 26	Magel	lanica	1630	☽	May 25	17 56	6 0
1618	☽	Feb. 9	3 29	2 57	1630	☉	June 10	7 47	9 8
1618	☉	July 21	Mexico	———	1630	☽	Nov. 19	11 24	9 27
1619	☉	Jan. 15	Califor	nia	1630	☉	Dec. 3	N. Gui.	10 10
1619	☽	June 20	12 4[illegible]	3 10	1631	☉	Apr. 30	Antar.	Circle
1619	☉	July 11	Africa	11 39	1631	☽	May 15	8 15	Total
1619	☽	Dec. 20	15 53	10 47	1631	☉	Oct. 24	C Good	Hope
1620	☉	May 31	Arctic	Circle	1631	☽	Nov. 8	12 0	Total
1620	☽	June 14	13 47	Total	1632	☉	Apr. 19	C Good	Hope
1620	☉	June 29	Magel.	7 20	1632	☽	May 4	1 24	6 35
1620	☽	Dec. 9	6 39	Total	1632	☉	Oct. 13	Mexico	8 37
1620	☉	Dec. 23	Magel	lanica	1632	☽	Oct. 27	12 23	5 31
1621	☉	May 20	14 54	10 44	1633	☉	April 8	5 14	4 30
1621	☽	June 3	19 42	9 53	1633	☉	Oct. 3	Maldiv.	Total
1621	☉	Nov. 13	Magel	lanica	1634	☽	Mar. 14	9 35	11 18
1621	☽	Nov. 28	15 43	3 38	1634	☉	Mar. 28	Japan	10 19
1622	☉	May 10	C. Verd	11 52	1634	☽	Sept. 7	5 0	Total
1622	☉	Nov. 2	Malac	ca In.	1634	☉	Sept. 22	C.G.H.	9 54
1623	☽	Apr. 14	7 19	10 54	1635	☉	Feb. 17	Antar.	Circle
1623	☉	Apr. 29	———	———	1635	☽	Mar. 3	9 25	Total
1623	☽	Oct. 8	0 22	8 35	1635	☉	Mar. 18	Mexico	0 16
1623	☉	Oct. 23	Califor.	10 46	1635	☉	Aug. 12	Iceland	5 0
1624	☉	May 18	N. Zem.	6 0	1635	☽	Aug. 27	16 4	Total
1624	☽	April 3	7 9	Total	1636	☉	Feb. 6	In	Peru
1624	☉	Apr. 17	Antar.	Circle	1636	☽	Feb. 20	11 34	3 23
1624	☉	Sept. 12	Magel	lanica	1636	☉	Aug. 1	Tartary	11 20
1624	☽	Sept. 26	8 55	Total	1636	☽	Aug. 16	4 34	1 25

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1637	☉	Jan. 25	Cam	boya	1649	☉	June 9	Arct. C.	4 c
1637	☉	July 21	Jucutan		1649	☉	Nov. 4	2 10	5 1c
1637	☽	Dec. 31	0 44	10 45	1649	☽	Nov. 18	19 56	Total
1638	☉	Jan. 14	Persia	9 45	1650	☉	Apr. 30	5 54	——
1638	☽	June 25	20 17	Total	1650	☽	May 15	8 37	7 57
1638	☉	July 11	Mag-	9 5	1650	☉	Oct. 24	17 17	——
1638	☉	Dec. 5	ellan.	2 10	1650	☽	Nov. 7	20 29	5 3
1638	☽	Dec. 20	15 16	Total	1651	☉	Apr. 19	Tuber.	——
1639	☉	Jan. 4	Tartary	0 30	1651	☉	Oct. 14	2 15	——
1639	☉	June 1	5 59	10 40	1652	☽	Mar. 24	16 52	8 50
1639	☽	June 15	2 41	11 9	1652	☉	April 7	22 40	9 59
1639	☉	Nov. 24	Magel.	11 0	1652	☽	Sept. 17	7 27	9 49
1639	☽	Dec. 9	11 57	3 46	1652	☉	Oct. 2	5 2	——
1640	☉	May 20	N. Spa.	10 30	1653	☉	Feb. 27	——	——
1640	☉	Nov. 13	Peru	10 36	1653	☽	Mar. 13	17 9	Total
1641	☽	Apr. 25	1 2	9 49	1653	☉	Aug. 22	——	——
1641	☉	May 9	Peru	10 16	1653	☽	Sept. 6	23 45	Total
1641	☽	Oct. 18	8 19	6 31	1654	☉	Feb. 16	9 10	——
1641	☉	Nov. 2	18 46	——	1654	☽	Mar. 2	19 25	3 14
1642	☉	Mar. 30	Estotl.	4 0	1654	☉	Aug. 11	22 24	2 28
1642	☽	Apr. 14	14 31	Total	1654	☽	Aug. 27	11 49	1 53
1642	☉	Sept. 25	Magel	lanica	1655	☉	Feb. 6	2 37	4 20
1642	☽	Oct. 7	16 45	Total	1655	☉	Aug. 1	14 19	——
1643	☉	Mar. 19	13 53	——	1655	☽	Aug. 16	16 —	*
1643	☽	April 3	21 10	3 9	1656	☽	Jan. 11	9 4	10 0
1643	☉	Sept. 12	17 0	——	1656	☽	July 6	3 17	Total
1643	☽	Sept. 27	7 38	6 0	1656	☉	July 21	11 48	——
1644	☉	Mar. 8	6 20	——	1656	☽	Dec. 30	23 30	Total
1644	☉	Aug. 31	18 10	——	1657	☉	June 11	11 20	——
1645	☽	Feb. 10	7 45	8 52	1657	☽	June 25	9 35	Total
1645	☉	Feb. 26	Rom. I.	10 46	1657	☉	Dec. 4	20 0	——
1645	☽	Aug. 7	2 4	Total	1657	☽	Dec. 20	7 47	3 9
1645	☉	Aug. 21	0 35	4 40	1658	☉	May 31	16 0	——
1646	☉	Jan. 16	Str. of	Anian	1658	☽	June 14	22 58	——
1646	☽	Jan. 30	18 11	Total	1658	☽	Nov. 9	13 56	0 10
1646	☉	July 12	6 57	——	1658	☉	Nov. 24	11 36	——
1646	☽	July 27	6 2	Total	1659	☽	May 6	8 34	8 5
1647	☉	Jan. 5	12 10	——	1659	☉	May 20	17 4	——
1647	☽	Jan. 20	9 43	4 47	1659	☽	Oct. 29	16 16	5 52
1647	☉	July 2	0 9	——	1659	☉	Nov. 14	4 25	9 51
1647	☉	Dec. 25	13 38	——	1660	☽	Apr. 24	21 58	Total
1648	☽	June 5	0 55	4 28	1660	☉	Oct. 3	22 34	——
1648	☉	June 20	13 28	——	1660	☽	Oct. 18	0 32	Total
1648	☽	Nov. 29	19 17	7 40	1660	☉	Nov. 2	13 48	——
1648	☉	Dec. 13	21 48	——	1661	☉	Mar. 25	22 32	——
1649	☽	May 25	15 20	Total	1661	☽	Apr. 14	4 28	——

RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1661	☉	Sept.23	1 36	11 19	1676	☽	June 25	6 26	——
1661	☽	Oct. 7	14 51	7 4	1676	☉	Dec. 4	20 52	——
1662	☉	Mar.19	15 8	——	1677	☉	Nov.24	12 5	——
1662	☉	Apr.12	1 8	——	1677	☽	May 16	16 25	8 15
1663	☽	Feb. 21	16 11	3 14	1678	☽	May 6	5 30	——
1663	☉	Mar. 9	5 47	——	1678	☽	Oct. 29	9 17	Total
1663	☽	Aug.18	8 45	Total	1679	☉	Apr.10	21 0	——
1663	☉	Sept. 1	8 8	——	1679	☽	May 25	11 53	5 47
1664	☉	Jan. 27	20 40	——	1680	☉	Mar.29	23 22	——
1664	☽	Feb. 11	3 16	——	1980	☉	Sept.22	7 57	——
1664	☉	July 22	14 48	——	1681	☽	Mar. 4	Noon	——
1664	☉	Aug.20	22 10	——	1681	☉	Mar.19	13 43	——
1665	☽	Jan. 30	18 47	4 34	1681	☽	Aug.28	15 22	10 35
1665	☉	July 12	7 48	——	1681	☉	Sept.11	15 43	——
1665	☽	July 26	13 31	0 10	1682	☽	Feb. 21	12 28	Total
1666	☉	Jan. 4	21 33	——	1682	☽	Aug.17	18 56	Total
1666	☉	July 1	19 0	11 10	1683	☉	Jan. 27	1 35	10 30
1667	☽	June 5	Noon	——	1683	☽	Feb. 9	3 39	——
1667	☉	July 21	2 32	——	1683	☽	Aug. 6	20 36	——
1667	☉	Nov.15	11 30	——	1684	☉	Jan. 16	6 34	——
1668	☉	May 10	Setting	——	1684	☽	June 26	15 18	1 35
1668	☽	May 25	16 26	9 32	1684	☉	July 12	3 26	Total
1668	☉	Nov. 4	2 53	9 50	1684	☽	Dec.21	11 18	9 45
1668	☽	Nov.18	3 54	6 45	1685	☉	Jan. 4	16 0	——
1669	☉	Apr.29	18 18	——	1685	☽	June 16	6 0	——
1669	☉	Oct. 24	10 13	——	1685	☽	Dec.10	11 26	Total
1670	☉	Apr.19	7 0	——	1686	☉	May 21	17 9	——
1670	☉	Sept.10	19 0	——	1686	☽	June 6	Noon	——
1670	☽	Sept.28	15 43	9 7	1686	☽	Nov.29	12 22	Total
1670	☉	Oct. 13	12 5	——	1687	☉	May 11	1 —	*
1671	☉	Apr. 8	23 29	——	1687	☽	May 26	14 —	*
1671	☉	Sept. 2	21 25	——	1687	☽	Apr.15	7 4	6 49
1671	☽	Sept.18	7 44	Total	1688	☉	Apr.29	16 27	——
1672	☉	Feb. 28	3 38	——	1688	☽	Oct. 9	Noon	——
1672	☽	Mar.13	3 17	——	1688	☉	Oct. 25	19 40	——
1672	☉	Aug.22	6 43	——	1689	☽	Apr. 4	7 42	Total
1672	☽	Sept. 6	18 54	——	1689	☽	Sept.28	15 46	Total
1673	☉	Feb. 16	7 29	——	1690	☉	Mar.10	——	——
1673	☉	Aug.11	21 44	——	1690	☽	Mar.24	11 14	5 43
1674	☽	Jan. 21	18 22	11 21	1690	☉	Sept. 3	——	——
1674	☉	Feb. 5	9 4	——	1690	☽	Sept.18	2 42	——
1674	☽	July 17	9 40	Total	1691	☉	Feb. 27	17 30	——
1675	☽	Jan. 11	8 29	Total	1691	☉	Aug.23	5 51	——
1675	☉	Jan. 25	10 36	——	1692	☽	Feb. 2	3 20	——
1675	☽	July 6	16 31	Total	1692	☉	Feb. 16	17 31	——
1676	☉	June 10	21 26	4 34	1692	☽	July 27	16 9	Total

RICCIOLUS's

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RICCIOLUS's Catalogue of ECLIPSES.

Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed	Aft. Chr.		M.&D.	Middle H. M.	Digits eclipsed
1693	☽	Jan. 21	17 25	Total	1696	☉	Nov.23	17 32	——
1693	☽	July 17	Noon	——	1697	☉	Apr.20	14 32	——
1694	☽	Jan. 11	Noon	——	1697	☽	May 5	18 27	——
1694	☉	June 22	4 22	6 22	1697	☽	Oct. 29	8 44	8 54
1694	☽	July 6	13 51	0 47	1698	☉	Apr.10	9 13	——
1695	☉	May 11	6 3	——	1698	☉	Oct. 3	15 29	——
1695	☽	May 28	Noon	——	1699	☽	Mar.15	8 14	9 7
1695	☽	Nov 20	8 0	6 55	1699	☉	Mar.30	22 0	——
1695	☉	Dec 5	17 7	——	1699	☽	Sept. 8	23 22	——
1696	☽	May 16	12 45	Total	1699	☉	Sept.23	22 38	9 58
1696	☉	May 30	12 56	——	1700	☽	Mar. 4	20 11	——
1696	☽	Nov 8	17 30	Total	1700	☽	Aug.29	1 42	——

The Eclipses from STRUYK were observed; those from RICCIOLUS calculated: the following from *L'Art de verifier les Dates*, are only those which are visible in *Europe* for the present century: those which are total are marked with a *T*; and *M* signifies Morning, *A* Afternoon.

Visible ECLIPSES from 1700 to 1800.

Aft. Chr.		Months and Days.	Time of the Day or Night.	Aft. Chr.		Months and Days.	Time of the Day or Night.
1701	☽	Feb. 22	11 A.	1715	☉	May 3	9 M. *T*.
1703	☽	Jan. 3	7 M.	1715	☽	Nov.11	5 M.
1703	☽	June 29	1 M. *T*.	1717	☽	Mar.27	3 M.
1703	☽	Dec. 23	7 M. *T*.	1717	☽	May 20	6 A.
1704	☽	Dec. 11	7 M.	1718	☽	Sept. 9	8 A. *T*.
1706	☽	Apr 28	2 M.	1719	☽	Aug.29	9 A.
1706	☉	May 12	10 M.	1721	☽	Jan. 13	3 A.
1706	☽	Oct. 21	7 A.	1722	☽	June 29	3 M.
1707	☽	Apr. 17	2 M. *T*.	1722	☉	Dec. 8	3 A.
1708	☽	Apr. 5	6 M.	1722	☽	Dec. 22	4 A.
1708	☉	Dec. 14	8 M.	1724	☉	May 22	7 A. *T*.
1708	☽	Sept.29	9 A.	1724	☽	Nov. 1	4 M.
1709	☉	Mar.11	2 A.	1725	☽	Oct. 21	7 A.
1710	☽	Feb. 13	11 A.	1726	☉	Sept.25	6 A.
1710	☉	Feb. 28	1 A.	1726	☽	Oct. 11	5 M.
1711	☉	July 15	8 A.	1727	☉	Sept.15	7 M.
1711	☽	July 29	6 A. *T*.	1729	☽	Feb. 13	9 A. *T*.
1712	☽	Jan. 23	8 A.	1729	☽	Aug. 9	1 M.
1713	☽	June 8	6 A.	1730	☽	Feb. 4	4 M.
1713	☽	Dec. 2	4 M.	1731	☽	June 20	2 M.

Visible

Visible ECLIPSES from 1700 to 1800.

Aft. Chr.		Months and Days.	Time of the Day or Night.	Aft. Chr.		Months and Days.	Time of the Day or Night.
1732	☽	Dec. 1	10 A. T.	1764	☉	Apr. 1	10 M.
1733	☉	May 13	7 A.	1764	☽	Apr. 16	1 M.
1733	☽	May 28	7 A.	1765	☉	Mar. 21	2 A.
1735	☽	Oct. 2	1 M.	1765	☉	Aug. 16	5 A.
1736	☽	Mar. 25	12 A. T.	1766	☽	Feb. 24	7 A.
1736	☽	Sept. 20	3 M. T.	1766	☉	Aug. 5	7 A.
1736	☉	Oct. 4	6 A.	1768	☽	Jan. 4	5 M.
1737	☉	Mar. 1	4 A.	1768	☽	June 30	4 M. T.
1737	☽	Sept. 9	4 M.	1768	☽	Dec. 23	4 A. T.
1738	☉	Aug. 15	11 M.	1769	☉	June 4	8 M.
1739	☽	Jan. 24	11 A.	1769	☽	Dec. 13	7 M.
1739	☉	Aug. 4	5 A.	1770	☉	Nov. 17	10 M.
1739	☉	Dec. 30	9 M.	1771	☽	Apr. 28	2 M.
1740	☽	Jan. 13	11 A. T.	1771	☽	Oct. 23	5 A.
1741	☽	Jan. 1	12 A.	1772	☽	Oct. 11	6 A. T.
1743	☽	Nov. 2	3 M. T.	1772	☉	Oct. 26	10 M.
1744	☽	Aug. 26	9 A.	1773	☉	Mar. 23	5 M.
1746	☽	Aug. 30	12 A.	1773	☽	Sept. 30	7 A.
1747	☽	Feb. 14	5 M. T.	1774	☉	Mar. 12	10 M.
1748	☉	July 25	11 M.	1776	☽	July 31	1 M. T.
1748	☽	Aug. 8	12 A.	1776	☉	Aug. 14	5 M.
1749	☽	Dec. 23	8 A.	1777	☉	Jan. 9	5 A.
1750	☉	Jan. 8	9 M.	1778	☉	June 24	4 A.
1750	☽	June 19	9 A. T.	1778	☽	Dec. 4	6 M.
1750	☽	Dec. 13	7 M.	1779	☽	May 30	5 M. T.
1751	☽	June 9	2 M.	1779	☉	June 14	8 M.
1751	☽	Dec. 2	10 A.	1779	☽	Nov. 23	8 A.
1752	☉	May 13	8 A.	1780	☉	Oct. 27	6 A.
1753	☽	Apr. 17	7 A.	1780	☽	Nov. 12	4 M.
1753	☉	Oct. 26	10 M.	1781	☉	Apr. 23	6 A.
1755	☽	Mar. 28	1 M.	1781	☉	Oct. 17	8 M.
1757	☽	Feb. 4	6 M.	1782	☽	Apr. 12	7 A.
1757	☽	July 30	12 A.	1783	☽	Mar. 18	9 A. T.
1758	☽	Jan. 24	7 M. T.	1783	☽	Sept. 10	11 A. T.
1758	☉	Dec. 30	7 M.	1784	☽	Mar. 7	3 M.
1759	☉	June 24	7 A.	1785	☉	Feb. 9	1 A.
1759	☉	Dec. 19	2 A.	1787	☽	Jan. 3	12 A. T.
1760	☽	May 29	9 A.	1787	☉	Jan. 19	10 M.
1760	☉	June 13	7 M.	1787	☉	June 15	5 A.
1760	☽	Nov. 22	9 A.	1787	☽	Dec. 24	3 A.
1761	☽	May 18	11 A. T.	1788	☉	June 4	9 M.
1762	☽	May 8	4 M.	1789	☽	Nov. 2	12 A.
1762	☉	Oct. 17	8 M.	1790	☽	Apr. 28	12 A. T.
1762	☽	Nov. 1	8 A.	1790	☽	Oct. 23	1 M. T.
1763	☉	Apr. 13	8 M.	1791	☉	Apr. 3	1 A.

Viſible ECLIPSES from 1700 to 1800.

Aſt. Chr.		Months and Days	Time of the Day or Night.	Aſt. Chr.		Months and Days.	Time of the Day or Night.
1791	☽	Oct. 12	3 M.	1795	☽	Feb. 4	1 M.
1792	☉	Sept. 16	11 M.	1795	☉	July 16	9 M.
1793	☽	Feb. 25	10 A.	1795	☽	July 31	8 A.
1793	☉	Sept. 5	3 A.	1797	☉	June 25	8 A.
1794	☉	Jan. 31	4 A.	1797	☽	Dec. 4	6 M.
1794	☽	Feb. 14	11 A. *T.*	1798	☽	May 27	7 A. *T.*
1794	☉	Aug. 25	5 A.	1800	☽	Oct. 2	11 A.

328. *A Liſt of Eclipſes, and hiſtorical Events, which happened about the ſame Times, from* RICCIOLUS.

Before CHRIST.

754	*July* 5	But according to an old Calendar, this Eclipſe of the Sun was on the 21ſt of *April*, on which day the Foundations of *Rome* were laid; if we may believe *Taruntius Firmanus*.
721	*March* 19	A total Eclipſe of the Moon. The *Aſſyrian* Empire at an end; the *Babylonian* eſtabliſhed.
585	*May* 28	An Eclipſe of the Sun foretold by THALES, by which a peace was brought about between the *Medes* and *Lydians*. Hiſtorical Eclipſe.
523	*July* 16	An Eclipſe of the Moon, which was followed by the death of CAMBYSES.
502	*Nov.* 19	An Eclipſe of the Moon, which was followed by the ſlaughter of the *Sabines*, and death of *Valerius Publicola*.
463	*April* 30	An Eclipſe of the Sun. The *Perſian* war, and the falling off of the *Perſians* from the *Egyptians*.

S An

Before Christ.		
431	*April* 25	An Eclipse of the Moon, which was followed by a great famine at *Rome*; and the beginning of the *Peloponnesian* war.
431	*August* 3	A total Eclipse of the Sun. A Comet and Plague at *Athens* *.
413	*August* 27	A total Eclipse of the Moon. *Nicias* with his ship destroyed at *Syracuse*.
394	*August* 14	An Eclipse of the Sun. The *Persians* beat by *Conon* in a sea engagement.
168	*June* 21	A total Eclipse of the Moon. The next day *Perseus* King of *Macedonia* was conquered by *Paulus Emilius*.
After Christ.		
59	*April* 30	An Eclipse of the Sun. This is reckoned among the prodigies, on account of the murder of *Agrippinus* by *Nero*.
237	*April* 12	A total Eclipse of the Sun. A sign that the reign of the *Gordiani* would not continue long. A sixth persecution of the Christians.
306	*July* 27	An Eclipse of the Sun. The Stars were seen, and the Emperor *Constantius* died.
840	*May* 4	A dreadful Eclipse of the Sun. And *Lewis* the Pious died within six months after it.
1009	———	An Eclipse of the Sun. And *Jerusalem* taken by the *Saracens*.
1133	*August* 2	A terrible Eclipse of the Sun. The Stars were seen. A schism in the church, occasioned by there being three Popes at once.

* This Eclipse happened in the first year of the *Peloponnesian* war.

329. I have not cited one half of RICCIOLUS's list of portentous Eclipses; and for the same reason that he declines giving any more of them than what that list contains; namely, that it is most disagreeable to dwell any longer on such nonsense, and as much as possible to avoid tiring the reader: the superstition of the antients may be seen by the few here copied. My author farther says, that there were treatises written to shew against what regions the malevolent effects of any particular Eclipse was aimed: and the writers affirmed, that the effects of an Eclipse of the Sun continued as many years as the Eclipse lasted hours; and that of the Moon as many months.

The superstitious notions of the antients with regard to Eclipses.

330. Yet such idle notions were once of no small advantage to CHRISTOPHER COLUMBUS; who, in the year 1493, was driven on the island of *Jamaica*, where he was in the greatest distress for want of provisions, and was moreover refused any assistance from the inhabitants; on which he threatened them with a plague, and told them, that in token of it, there should be an Eclipse: which accordingly fell on the day he had foretold, and so terrified the Barbarians, that they strove who should be first in bringing him all sorts of provisions; throwing them at his feet, and imploring his forgiveness. RICCIOLUS's *Almagest*, Vol. I. l. v. c. ii.

Very fortunate once for CHRISTOPHER COLUMBUS.

331. Eclipses of the Sun are more frequent than of the Moon, because the Sun's ecliptic limits are greater than the Moon's, § 317: yet we have more visible Eclipses of the Moon than of the Sun, because Eclipses of the Moon are seen from all parts of that Hemisphere of the Earth which is next her, and are equally great to each of those parts; but the Sun's Eclipses are visible only to that small portion of the Hemisphere next him whereon the Moon's shadow falls; as shall be explained by and by at large.

Why there are more visible Eclipses of the Moon than of the Sun.

332. The Moon's Orbit being elliptical, and the Earth in one of it's focuses, she is once at her

PLATE XI. Fig. 1.

leaſt diſtance from the Earth, and once at her greateſt, in every Lunation. When the Moon changes at her leaſt diſtance from the Earth, and ſo near the Node that her dark ſhadow falls upon the Earth, ſhe appears big enough to cover the whole * Diſc of the Sun from that part on which her ſhadow falls; and the Sun appears totally eclipſed there, as at *A*, for ſome minutes: but when the Moon changes at her greateſt diſtance from the Earth, and ſo near the Node that her dark ſhadow is directed towards the Earth, her diameter ſubtends a leſs angle than the Sun's; and therefore ſhe cannot hide his whole Diſc from any part of the Earth, nor does her ſhadow reach it at that time; and to the place over which the point of her ſhadow hangs, the Eclipſe is annular, as at *B*; the Sun's edge appearing like a luminous ring all around the body of the Moon. When the Change happens within 17 degrees of the Node, and the Moon at her mean diſtance from the Earth, the point of her ſhadow juſt touches the Earth, and ſhe eclipſeth the Sun totally to that ſmall ſpot whereon her ſhadow falls; but the darkneſs is not of a moment's continuance.

Total and annular Eclipſes of the Sun.

The longeſt duration of total Eclipſes of the Sun.

333. The Moon's apparent diameter when largeſt exceeds the Sun's when leaſt, only 1 minute 38 ſeconds of a degree: and in the greateſt Eclipſe of the Sun that can happen at any time and place, the total darkneſs continues no longer than whilſt the Moon is going 1 minute 38 ſeconds from the Sun in her Orbit; which is about 3 minutes and 13 ſeconds of an hour.

To how much of the Earth the Sun may be totally or partially eclipſed at once.

334. The Moon's dark ſhadow covers only a ſpot on the Earth's ſurface, about 180 *Engliſh* miles broad, when the Moon's diameter appears largeſt

* Although the Sun and Moon are ſpherical bodies, as ſeen from the Earth they appear to be circular planes; and ſo would the Earth do, if it were ſeen from the Moon. The apparently flat ſurfaces of the Sun and Moon are called their *Diſcs* by Aſtronomers.

2 and

Plate XI.

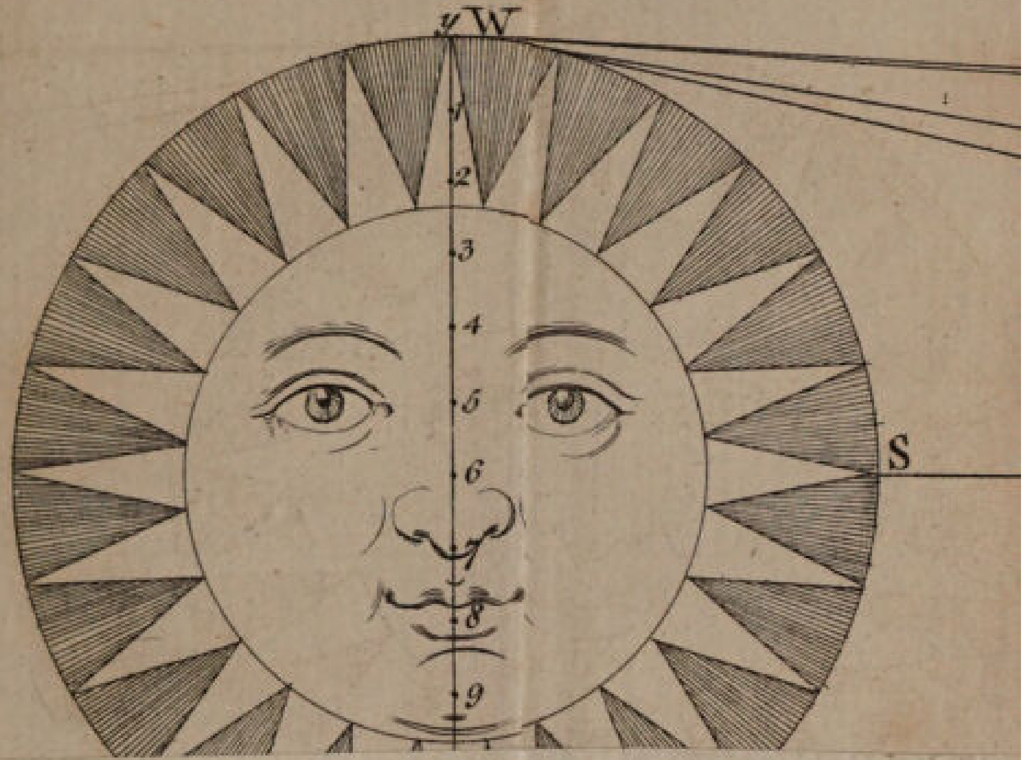
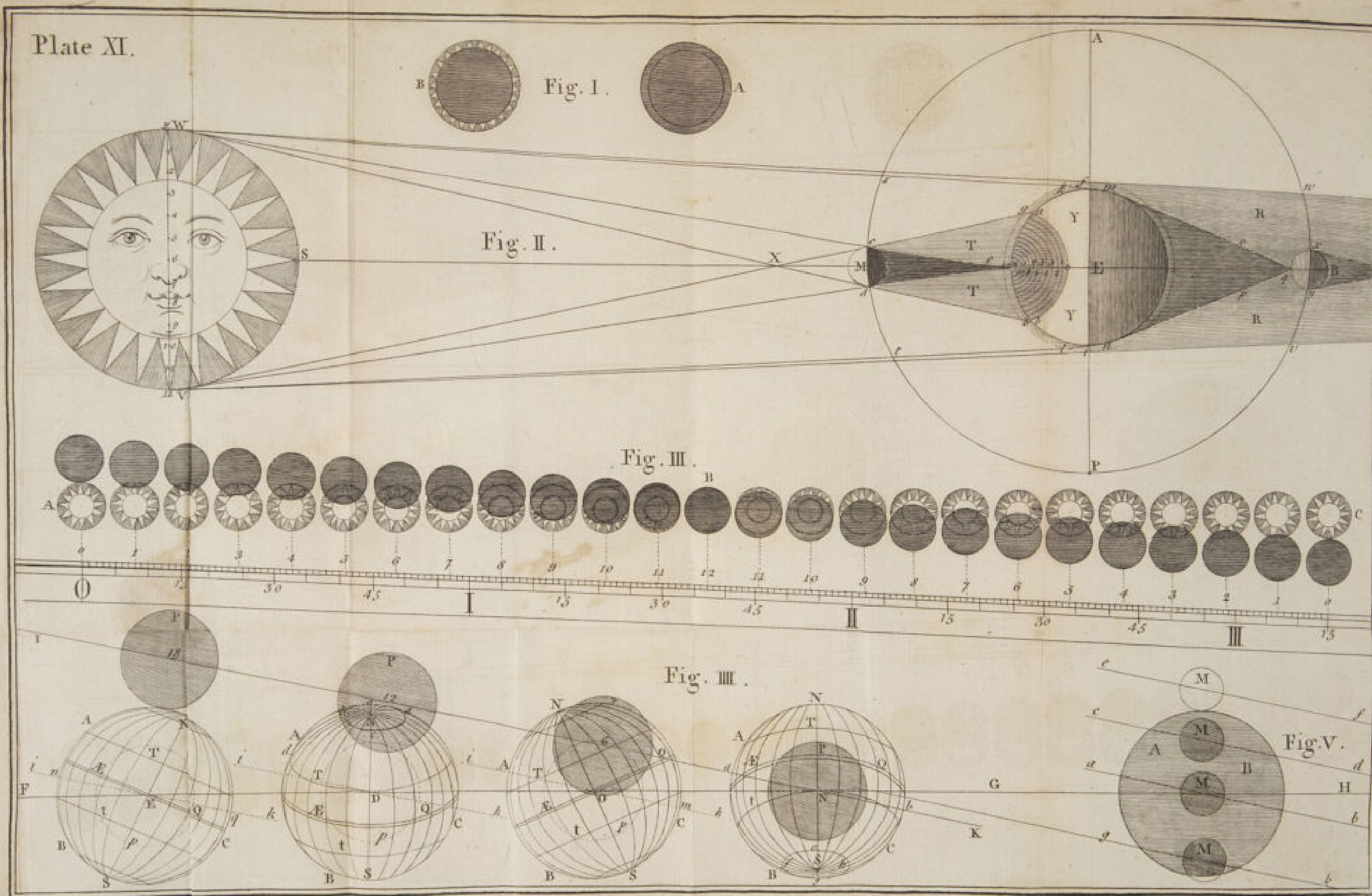


Plate XI.



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and the Sun's least; and the total darkness can extend no farther than the dark shadow covers. Yet the Moon's partial Shadow or Penumbra may then cover a circular space 4900 miles diameter, within all which the Sun is more or less eclipsed, as the places are less or more distant from the Center of the Penumbra. When the Moon changes exactly in the Node, the Penumbra is circular on the Earth at the middle of the general Eclipse; because at that time it falls perpendicularly on the Earth's surface: but at every other moment it falls obliquely, and will therefore be elliptical; and the more so, as the time is longer before or after the middle of the general Eclipse; and then, much greater portions of the Earth's surface are involved in the Penumbra. PLATE XI.

335. When the Penumbra first touches the Earth, the general Eclipse begins: when it leaves the Earth, the general Eclipse ends: from the beginning to the end the Sun appears eclipsed in some part of the Earth or other. When the Penumbra touches any place, the Eclipse begins at that place, and ends when the Penumbra leaves it. When the Moon changes in the Node, the Penumbra goes over the center of the Earth's Disc as seen from the Moon; and consequently, by describing the longest line possible on the Earth, continues the longest upon it; namely, at a mean rate, 5 hours 50 minutes: more, if the Moon be at her greatest distance from the Earth, because she then moves slowest; less, if she be at her least distance, because of her quicker motion. Duration of general and particular Eclipses.

336. To make the last five articles and several other Phenomena plainer, let *S* be the Sun, *E* the Earth, *M* the Moon, and *A M P* the Moon's Orbit. Draw the right line *W c* 12 from the western side of the Sun at *W*, touching the western side of the Moon at *c*, and the Earth at 12: draw also the right line *V d* 12 from the eastern side of the Sun at *V*, touching the eastern side of the Moon at *d*, Fig. II.

the Earth at 12: the dark space *c e* 12 *d* included between those lines is the Moon's shadow, ending in a point at 12, where it touches the Earth; because in this case the Moon is supposed to change at *M* in the middle between *A* the Apogee, or farthest point of her Orbit from the Earth, and *P* the Perigree, or nearest point to it. For, had the point *P* been at *M*, the Moon had been nearer the Earth; and her dark shadow at *e* would have covered a space upon it about 180 miles broad, and the Sun would have been totally darkened, as at *A* (Fig. I.) with some continuance: but had the point *A* (Fig. II.) been at *M*, the Moon would have been farther from the Earth, and her shadow would have ended in a point about *e*, and therefore the Sun would have appeared, as at *B* (Fig. I.) like a luminous ring all around the Moon. Draw the right lines *W X d b* and *V X c g*, touching the contrary sides of the Sun and Moon, and ending on the Earth at *a* and *b*: draw also the right line *S X M* 12, from the center of the Sun's Disc, through the Moon's center, to the Earth at 12; and suppose the two former lines *W X d b* and *V X c g* to revolve on the line *S X M* 12 as an Axis, and their points *a* and *b* will describe the limits of the Penumbra *T T* on the Earth's surface, including the large space *a o b* 12 *a*; within which the Sun appears more or less eclipsed, as the places are more or less distant from the verge of the Penumbra *a o b*.

The Moon's dark shadow, and Penumbra.

Digits, what.

Draw the right line *y* 12 across the Sun's Disc, perpendicular to *S X M* the Axis of the Penumbra; then, divide the line *y* 12 into twelve equal parts, as in the Figure, for the twelve * Digits of the Sun's diameter: and, at equal distances from the center of the Penumbra at 12 (on the Earth's surface *Y Y*) to it's edge *a o b*, draw twelve concentric Circles, as marked with the numeral Figures 1 2 3 4, &c. and remember that the Moon's motion

* A Digit is a twelfth part of the diameter of the Sun and Moon.

tion in her Orbit *AMP* is from weſt to eaſt, as from *s* to *t*. Then, PLATE XI.

To an obſerver on the Earth at *b*, the eaſtern limb of the Moon at *d* ſeems to touch the weſtern limb of the Sun at *W*, when the Moon is at *M*; and the Sun's Eclipſe begins at *b*, appearing as at *A* in Fig. III. at the left hand; but, at the ſame moment of abſolute time to an obſerver at *a* in Fig. II. the weſtern edge of the Moon at *c* leaves the eaſtern edge of the Sun at *V*, and the Eclipſe ends, as at the right hand *C* of Fig. III. At the very ſame inſtant, to all thoſe who live on the Circle marked 1 on the Earth *E* in Fig. II, the Moon *M* cuts off or darkens a twelfth part of the Sun *S*, and eclipſes him one Digit, as at 1 in Fig. III: to thoſe who live on the Circle marked 2 in Fig. II, the Moon cuts off two twelfth parts of the Sun, as at 2 in Fig. III: to thoſe on the Circle 3, three parts; and ſo on to the center at 12 in Fig. II, where the Sun is centrally eclipſed, as at *B* in the middle of Fig. III; under which Figure there is a ſcale of hours and minutes, to ſhew at a mean rate how long it is from the beginning to the end of a central Eclipſe of the Sun on the parallel of *London*; and how many Digits are eclipſed at any particular time from the beginning at *A* to the middle at *B*, or the end at *C*. Thus, in 16 minutes from the beginning, the Sun is two Digits eclipſed; in an hour and five minutes, eight Digits; and in an hour and thirty-ſeven minutes, 12 Digits.

The different Phaſes of a ſolar Eclipſe.

Fig. III.

337. By Fig. II. it is plain, that the Sun is totally or centrally eclipſed but to a ſmall part of the Earth at any time; becauſe the dark conical ſhadow *e* of the Moon *M* falls but on a ſmall part of the Earth: and that the partial Eclipſe is confined at that time to the ſpace included by the Circle *a o b*, of which only one half can be projected in the Figure, the other half being ſuppoſed to be hid by the convexity of the Earth *E*: and likewiſe, that no part of the Sun is eclipſed to the large ſpace *YY*

Fig. II.

PLATE XI. The Velocity of the Moon's shadow on the Earth. of the Earth, because the Moon is not between the Sun and any of that part of the Earth: and therefore to all that part the Eclipse is invisible. The Earth turns eastward on it's Axis, as from *g* to *h*, which is the same way that the Moon's shadow moves; but the Moon's motion is much swifter in her Orbit from *s* to *t*: and therefore, although Eclipses of the Sun are of longer duration on account of the Earth's motion on it's Axis than they would be if that motion was stopt, yet in four minutes of time at most, the Moon's swifter motion carries her dark shadow quite over any place that it's center touches at the time of greatest obscuration. The motion of the shadow on the Earth's Disc is equal to the Moon's motion from the Sun, which is about $30\frac{1}{2}$ minutes of a degree every hour at a mean rate; but so much of the Moon's Orbit is equal to $30\frac{1}{2}$ degrees of a great Circle on the Earth, § 320; and therefore the Moon's shadow goes $30\frac{1}{2}$ degrees or 1830 geographical miles on the Earth in an hour, or $30\frac{1}{2}$ miles in a minute, which is almost four times as swift as the motion of a cannon-ball.

338. As seen from the Sun or Moon, the Earth's Axis appears differently inclined every day of the year, on account of keeping it's parallelism through-

Fig. IV. out it's annual course. Let *E*, *D*, *O*, *N* be the Earth at the two Equinoxes and the two Solstices, *N S* it's Axis, *N* the North Pole, *S* the South Pole, *Æ Q* the Equator, *T* the tropic of Cancer, *t* the

Phenomena of the Earth as seen from the Sun or New Moon at different times of the year. tropic of Capricorn, and *A B C* the Circumference of the Earth's enlightened Disc as seen from the Sun or New Moon at these times. The Earth's Axis has the position *N E S* at the vernal Equinox, lying towards the right hand, as seen from the Sun or New Moon; it's Poles *N* and *S* being then in the Circumference of the Disc; and the Equator and all it's parallels seem to be straight lines, because their planes pass through the observer's eye looking down upon the Earth from the Sun or Moon

Moon directly over *E*, where the Ecliptic *FG* interſects the Equator *Æ*. At the Summer Solſtice, the Earth's Axis has the poſition *N D S*; and that part of the Ecliptic *FG*, in which the Moon is then New, touches the Tropic of Cancer *T* at *D*. The North Pole *N* at that time inclining $23\frac{1}{2}$ degrees towards the Sun, falls ſo many degrees within the Earth's enlightened Diſc, becauſe the Sun is then vertical to *D*, $23\frac{1}{2}$ degrees north of the Equator *Æ Q*; and the Equator with all it's parallels ſeem elliptic curves bending downward, or towards the South Pole, as ſeen from the Sun: which Pole, together with $23\frac{1}{2}$ degrees all round it, is hid behind the Diſc in the dark Hemiſphere of the Earth. At the autumnal Equinox, the Earth's Axis has the poſition *N O S*, lying to the left hand as ſeen from the Sun or New Moon, which are then vertical to *O*, where the Ecliptic cuts the Equator *Æ Q*. Both Poles now lie in the circumference of the Diſc, the North Pole juſt going to diſappear behind it, and the South Pole juſt entering into it; and the Equator with all it's parallels ſeem to be ſtraight lines, becauſe their planes paſs through the obſerver's eye, as ſeen from the Sun, and very nearly ſo as ſeen from the Moon. At the Winter Solſtice, the Earth's Axis has the poſition *N N S*; when it's South Pole *S* inclining $23\frac{1}{2}$ degrees towards the Sun, falls $23\frac{1}{2}$ degrees within the enlightened Diſc, as ſeen from the Sun or New Moon, which are then vertical to the Tropic of Capricorn *t*, $23\frac{1}{2}$ degrees ſouth of the Equator *Æ Q*; and the Equator with all it's parallels ſeem elliptic curves bending upward; the North Pole being as far behind the Diſc in the dark Hemiſphere, as the South Pole is come into the light. The nearer that any time of the year is to the Equinoxes or Solſtices, the more it partakes of the Phenomena relating to them.

339. Thus it appears, that from the vernal equinox to the autumnal, the North Pole is enlighten-

ed;

PLATE XI. Various positions of the Earth's Axis, as seen from the Sun at different times of the year.

ed; and the Equator and all it's parallels appear elliptical as seen from the Sun, more or less curved as the time is nearer to or farther from the Summer Solstice; and bending downwards, or towards the South Pole; the reverse of which happens from the autumnal Equinox to the vernal. A little consideration will be sufficient to convince the reader, that the Earth's Axis inclines towards the Sun at the Summer Solstice; from the Sun at the Winter Solstice; and sidewise to the Sun at the Equinoxes; but towards the right hand, as seen from the Sun at the vernal Equinox; and towards the left hand at the autumnal. From the Winter to the Summer Solstice, the Earth's Axis inclines more or less to the right hand, as seen from the Sun; and the contrary from the Summer to the Winter Solstice.

How these positions affect solar Eclipses.

340. The different positions of the Earth's Axis, as seen from the Sun at different times of the year, affect solar Eclipses greatly with regard to particular places; yea so far as would make central Eclipses which fall at one time of the year invisible if they had fallen at another, even though the Moon should always change in the Nodes, and at the same hour of the day: of which indefinitely various affections, we shall only give Examples for the times of the Equinoxes and Solstices.

Fig. IV.

In the same Diagram, let FG be part of the Ecliptic, and IK, ik, ik, ik part of the Moon's Orbit; both seen edgewise, and therefore projected into right lines; and let the intersections N, O, D, E be one and the same Node at the above times, when the Earth has the forementioned different positions; and let the space included by the Circles P, p, p, p be the Penumbra at these times, as it's center is passing over the center of the Earth's Disc. At the Winter Solstice, when the Earth's Axis has the position NNS, the center of the Penumbra P touches the Tropic of Capricorn t in N at the middle of the general Eclipse; but no part of of the Penumbra touches the Tropic of Cancer *T*. At the Summer Solstice, when the Earth's Axis has the position *N D S* (*i D k* being then part of the Moon's Orbit, whose Node is at *D*) the Penumbra *p* has it's center at *D*, on the Tropic of Cancer *T*, at the middle of the general Eclipse, and then no part of it touches the Tropic of Capricorn *t*. At the autumnal Equinox, the Earth's Axis has the position *N O S* (*i O k* being then part of the Moon's Orbit) and the Penumbra equally includes part of both Tropics *T* and *t* at the middle of the general Eclipse: at the vernal Equinox it does the same, because the Earth's Axis has the position *N E S*: but, in the former of these two last cases, the Penumbra enters the Earth at *A*, north of the Tropic of Cancer *T*, and leaves it at *m*, south of the Tropic of Capricorn *t*; having gone over the Earth obliquely southward, as it's center described the line *AOm*: whereas, in the latter case, the Penumbra touches the Earth at *n*, south of the Equator *Æ Q*, and describing the line *n E q* (similar to the former line *A O m* in open space) goes obliquely northward over the Earth, and leaves it at *q*, north of the Equator.

In all these circumstances, the Moon has been supposed to change at noon in her descending Node: had she changed in her ascending Node, the Phenomena would have been as various the contrary way, with respect to the Penumbra's going northward or southward over the Earth. But because the Moon changes at all hours, as often in one Node as in the other, and at all distances from them both at different times as it happens, the variety of the Phases of Eclipses are almost innumerable, even at the same places; considering also how variously the same places are situated on the enlightened Disc of the Earth, with respect to the Penumbra's motion, at the different hours when Eclipses happen.

341. When

How much of the Penumbra falls on the Earth at different distances from the Nodes.

341. When the Moon changes 17 degrees short of her descending Node, the Penumbra P 18 just touches the northern part of the Earth's Disc, near the North Pole N; and, as seen from that place, the Moon appears to touch the Sun, but hides no part of him from sight. Had the Change been as far short of the ascending Node, the Penumbra would have touched the southern part of the Disc near the South Pole S. When the Moon changes 12 degrees short of the descending Node, more than a third part of the Penumbra P 12 falls on the northern parts of the Earth at the middle of the general Eclipse: had she changed as far past the same Node, as much of the other side of the Penumbra about P would have fallen on the southern of the Earth; all the rest in the *expansum*, or open space. When the Moon changes 6 degrees from the Node, almost the whole Penumbra P 6 falls on the Earth at the middle of the general Eclipse. And lastly, when the Moon changes in the Node at N, the Penumbra $P N$ takes the longest course possible on the Earth's Disc; it's center falling on the middle thereof, at the middle of the general Eclipse. The farther the Moon changes from either Node, within 17 degrees of it, the shorter is the Penumbra's continuance on the Earth, because it goes over a less portion of the Disc, as is evident by the Figure.

The Earth's diurnal motion lengthens the duration of solar Eclipses, which fall without the polar Circles.

342. The nearer that the Penumbra's center is to the Equator at the middle of the general Eclipse, the longer is the duration of the Eclipse at all those places where it is central; because, the nearer that any place is to the Equator, the greater is the Circle it describes by the Earth's motion on it's Axis: and so, the place moving quicker, keeps longer in the Penumbra, whose motion is the same way with that of the place, though faster, as has been already mentioned, § 337. Thus (see the Earth at D and the Penumbra at 12) whilst the point b in the polar Circle $a\,b\,c\,d$ is carried from b

to

to *c* by the Earth's diurnal motion, the point *d* on the Tropic of Cancer *T* is carried a much greater length from *d* to *D*: and therefore, if the Penumbra's center goes one time over *c* and another time over *D*, the Penumbra will be longer in passing over the moving place *d* than it was in passing over the moving place *b*. Consequently, central Eclipses about the Poles are of the shortest duration; and about the Equator the longest.

343. In the middle of Summer, the whole frigid Zone included by the polar Circle *a b c d* is enlightened; and if it then happens that the Penumbra's center goes over the North Pole, the Sun will be eclipsed much the same number of Digits at *a* as at *c*; but whilst the Penumbra moves eastward over *c*, it moves westward over *a*, because, with respect to the Penumbra, the motions of *a* and *c* are contrary: for *c* moves the same way with the Penumbra towards *d*, but *a* moves the contrary way towards *b*; and therefore the Eclipse will be of longer duration at *c* than at *a*. At *a* the Eclipse begins on the Sun's eastern limb, but at *c* on his western: at all places lying without the polar Circles, the Sun's Eclipses begin on his western limb, or near it, and end on or near his eastern. At those places where the Penumbra touches the Earth, the Eclipse begins with the rising Sun, on the top of his western or uppermost edge; and at those places where the Penumbra leaves the Earth, the Eclipse ends with the setting Sun, on the top of his eastern edge, which is then the uppermost, just at it's disappearing in the Horizon. And shortens the duration of some which fall within these Circles.

344. If the Moon were surrounded by an Atmosphere of any considerable Density, it would seem to touch the Sun a little before the Moon made her appulse to his edge, and we should see a little faintness on that edge before it were eclipsed by the Moon: but as no such faintness has been observed, at least so far as I ever heard, it seems plain, that the Moon has no such Atmosphere as that The Moon has no Atmosphere.

of

PLATE XI. of the Earth. The faint ring of light ſurrounding the Sun in total Eclipſes, called by CASSINI *la Chevelure du Soleil,* ſeems to be the Atmoſphere of the Sun; becauſe it has been obſerved to move equally with the Sun, not with the Moon.

345. Having been ſo prolix concerning Eclipſes of the Sun, we ſhall drop that ſubject at preſent, and proceed to the doctrine of lunar Eclipſes; which, being more ſimple, may be explained in leſs time.

Eclipſes of the Moon. That the Moon can never be eclipſed but at the time of her being Full, and the reaſon why ſhe is not eclipſed at every Full, has been ſhewn already, § 316, 317. Let *S* be the Sun, *E* the Earth, *R R* the Earth's ſhadow, and *B* the Moon in oppoſition to the Sun: in this ſituation the Earth intercepts the Sun's light in it's way to the Moon; and when the Moon touches the Earth's ſhadow at *v*, ſhe begins to be eclipſed on her eaſtern limb *x*, and continues eclipſed until her weſtern limb *y* leaves the ſhadow at *w*: at *B* ſhe is in the middle of the ſhadow, and conſequently in the middle of the Eclipſe.

Fig. II.

346. The Moon when totally eclipſed is not inviſible, if ſhe be above the Horizon and the Sky be clear; but appears generally of a duſky colour like tarniſhed copper, which ſome have thought to be the Moon's native light. But the true cauſe of her being viſible is the ſcattered beams of the Sun, bent into the Earth's ſhadow by going through the Atmoſphere; which, being more denſe near the Earth than at conſiderable heights above it, refracts or bends the Sun's rays more inward, § 179, the nearer they are paſſing by the Earth's ſurface, than thoſe rays which go through higher parts of the Atmoſphere, where it is leſs denſe according to it's height, until it be ſo thin or rare as to loſe it's refractive power. Let the Circle *f g h i*, concentric to the Earth, include the Atmoſphere whoſe refractive power vaniſhes at the heights *f*

Why the Moon is viſible in a total Eclipſe.

6 and

and *i*; so that the rays *Wfw* and *Viv* go on straight without suffering the least refraction: But all those rays which enter the Atmosphere between *f* and *k*, and between *i* and *l*, on opposite sides of the Earth, are gradually more bent inward as they go through a greater portion of the Atmosphere, until the rays *Wk* and *Vl* touching the Earth at *m* and *n*, are bent so much as to meet at *q*, a little short of the Moon; and therefore the dark shadow of the Earth is contained in the space *moqpn*, where none of the Sun's rays can enter: all the rest *RR*, being mixed by the scattered rays which are refracted as above, is in some measure enlightened by them; and some of those rays falling on the Moon, give her the colour of tarnished copper, or of iron almost red hot. So that if the Earth had no Atmosphere, the Moon would be as invisible in total Eclipses as she is when New. If the Moon were so near the Earth as to go into it's dark shadow, suppose about *po*, she would be invisible during her stay in it; but visible before and after in the fainter shadow *RR*. PLATE XI.

347. When the Moon goes through the center of the Earth's shadow, she is directly opposite to the Sun: yet the Moon has been often seen totally eclipsed in the Horizon when the Sun was also visible in the opposite part of it: for, the horizontal refraction being almost 34 minutes of a of a degree, § 181, and the diameter of the Sun and Moon being each at a mean state but 32 minutes, the refraction causes both Luminaries to appear above the Horizon when they are really below it, § 179. Why the Sun and Moon are sometimes visible when the Moon is totally eclipsed.

348. When the Moon is Full at 12 degrees from either of her Nodes, she just touches the Earth's shadow, but enters not into it. Let *GH* be the Ecliptic, *ef* the Moon's Orbit where she is 12 degrees from the Node at her Full; *cd* her Orbit where she is 6 degrees from the Node, *ab* her Orbit where she is Full in the Node, *AB* the Fig. V.

Earth's

Duration of central Eclipses of the Moon.

Earth's ſhadow, and *M* the Moon. When the Moon deſcribes the line *e f*, ſhe juſt touches the ſhadow, but does not enter into it; when ſhe deſcribes the line *c d*, ſhe is totally though not centrally immerſed in the ſhadow; and when ſhe deſcribes the line *a b*, ſhe paſſes by the Node at *M* in the center of the ſhadow, and takes the longeſt line poſſible, which is a diameter, through it: and ſuch an Eclipſe being both total and central is of the longeſt duration, namely, 3 hours 57 minutes 6 ſeconds from the beginning to the end, if the Moon be at her greateſt diſtance from the Earth: and 3 hours 37 minutes 26 ſeconds, if ſhe be at her leaſt diſtance. The reaſon of this difference is, that when the Moon is fartheſt from the Earth, ſhe moves the ſloweſt; and when neareſt to it, quickeſt.

Digits.

349. The Moon's diameter, as well as the Sun's, is ſuppoſed to be divided into twelve equal parts, called *Digits*; and ſo many of theſe parts as are darkened by the Earth's ſhadow, ſo many Digits is the Moon eclipſed. All that the Moon is eclipſed above 12 Digits, ſhew how far the ſhadow of the Earth is over the body of the Moon, on that edge to which ſhe is neareſt at the middle of the Eclipſe.

Why the beginning and end of a lunar Eclipſe is ſo difficult to be determined by obſervation.

350. It is difficult to obſerve exactly either the beginning or ending of a lunar Eclipſe, even with a good Teleſcope; becauſe the Earth's ſhadow is ſo faint, and ill defined about the edges, that when the Moon is either juſt touching or leaving it, the obſcuration of her limb is ſcarce ſenſible; and therefore the niceſt obſervers can hardly be certain to four or five ſeconds of time. But both the beginning and ending of ſolar Eclipſes are viſibly inſtantaneous; for the moment that the edge of the Moon's Diſc touches the Sun's, his roundneſs ſeems a little broke on that part; and the moment ſhe leaves it, he appears perfectly round again.

351. In

351. In Aſtronomy, Eclipſes of the Moon are of great uſe for aſcertaining the periods of her motions; eſpecially ſuch Eclipſes as are obſerved to be alike in all circumſtances, and have long intervals of time between them. In Geography, the Longitudes of places are found by Eclipſes, as already ſhewn in the eleventh chapter: but for this purpoſe Eclipſes of the Moon are more uſeful than thoſe of the Sun, becauſe they are more frequently viſible, and the ſame lunar Eclipſe is of equal largeneſs and duration at all places where it is ſeen. In Chronology, both ſolar and lunar Eclipſes ſerve to determine exactly the time of any paſt event: for there are ſo many particulars obſervable in every Eclipſe, with reſpect to it's quantity, the places where it is viſible (if of the Sun) and the time of the day or night; that it is impoſſible there can be two ſolar Eclipſes in the courſe of many ages which are alike in all circumſtances.

The uſe of Eclipſes in Aſtronomy, Geography, and Chronology.

352. From the above explanation of the doctrine of Eclipſes it is evident, that the darkneſs at our SAVIOUR's crucifixion was ſupernatural. For he ſuffered on the day on which the Paſſover was eaten by the *Jews*, on which day it was impoſſible that the Moon's ſhadow could fall on the Earth; for the *Jews* kept the Paſſover at the time of Full Moon: nor does the darkneſs in total Eclipſes of the Sun laſt above four minutes in any place, § 333, whereas the darkneſs at the crucifixion laſted three hours, *Matt.* xxviii. 15. and overſpread at leaſt all the land of *Judea*.

The darkneſs at our SAVIOUR's crucifixion ſupernatural.

T CHAP.

CHAP. XIX.

Shewing the Principles on which the following Astronomical Tables are constructed, and the Method of calculating the Times of New and Full Moons and Eclipses by them.

353. THE nearer that any object is to the eye of an observer, the greater is the angle under which it appears: the farther from the eye, the less.

The diameters of the Sun and Moon subtend different angles at different times. And, at equal intervals of time, these angles are once at the greatest, and once at the least, in somewhat more than a compleat revolution of the Luminary through the Ecliptic, from any given fixed Star to the same Star again.—This proves that the Sun and Moon are constantly changing their distances from the Earth; and that they are once at their greatest distance, and once at their least, in little more than a compleat revolution.

The gradual differences of these angles are not what they would be, if the Luminaries moved in circular Orbits, the Earth being supposed to be placed at some distance from the center: but they agree perfectly with elliptic orbits, supposing the lower focus of each orbit to be at the center of the Earth.

The farthest point of each Orbit from the Earth's center is called the *Apogee*, and the nearest point is called the *Perigee*.—These points are directly opposite to each other.

Astronomers divide each Orbit into 12 equal parts, called *Signs*; each sign into 30 equal parts, called *Degrees*; each degree into 60 equal parts, called *Minutes*; and every minute into 60 equal parts, called *Seconds*. The distance of the Sun or Moon from any given point of it's orbit, is reckoned

oned in ſigns, degrees, minutes, and ſeconds. Here we mean the diſtance that the Luminary has moved through from any given point; not the ſpace it is ſhort thereof in coming round again, though ever ſo little.

The diſtance of the Sun or Moon from it's Apogee, at any given time, is called it's *mean Anomaly:* ſo that, in the Apogee, the anomaly is nothing; in the Perigee, it is ſix ſigns.

The motions of the Sun and Moon are obſerved to be continually accelerated from the Apogee to the Perigee, and as gradually retarded from the Perigee to the Apogee; being ſloweſt of all when the mean anomaly is nothing, and ſwifteſt of all when it is ſix ſigns.

When the Luminary is in it's Apogee or Perigee, it's place is the ſame as it would be, if it's motion were equable in all parts of it's Orbit.—The ſuppoſed equable motions are called *mean*; the unequable are juſtly called the *true*.

The mean place of the Sun or Moon, is always forwarder than the true place*, whilſt the Luminary is moving from it's Apogee to it's Perigee; and the true place is always forwarder than the mean, whilſt the Luminary is moving from it's Perigee to it's Apogee.—In the former caſe, the anomaly is always leſs than ſix ſigns; and in the latter caſe, more.

It has been found, by a long ſeries of obſervations, that the Sun goes through the Ecliptic, from the *Vernal Equinox* to the ſame Equinox again, in 365 days 5 hours 48 minutes 55 ſeconds: from the *firſt Star of Aries* to the ſame Star again, in 365 days 6 hours 9 minutes 24 ſeconds: and from his *Apogee* to the ſame again, in 365 days 6 hours 14 minutes 0 ſeconds.—The firſt of theſe is called the *Solar Year*, the ſecond the *Sydereal Year*, and the third

* The point of the Ecliptic in which the Sun or Moon is, at any given moment of time, is called the *place* of the Sun or Moon at that time.

 the

the *Anomalistic Year*. So that the Solar Year is 20 minutes 29 seconds shorter than the Sydereal; and the Sydereal Year is 4 minutes 36 seconds shorter than the Anomalistic.—Hence it appears, that the *Equinoctial Point*, or intersection of the Ecliptic and Equator at the beginning of Aries, goes backward with respect to the fixed Stars, and that the Sun's Apogee goes forward.

It is also observed, that the Moon goes through her Orbit, from any given fixed Star to the same Star again, in 27 days 7 hours 43 minutes 4 seconds, at a mean rate: from her Apogee to her Apogee again, in 27 days, 13 hours 18 minutes 43 seconds: and from the Sun to the Sun again, in 29 days 12 hours 44 minutes $3\frac{1}{20}$ seconds.—This shews, that the Moon's Apogee moves forward in the Ecliptic, and *that* at a much quicker rate than the Sun's Apogee does; since the Moon is 5 hours 55 minutes 39 seconds longer in revolving from her Apogee to her Apogee again, than from any Star to the same Star again.

The Moon's Orbit crosses the Ecliptic in two opposite points, which are called her *Nodes*: and it is observed that she revolves sooner from any Node to the same Node again, than from any Star to the same Star again, by 2 hours 38 minutes 27 seconds, which shews that her Nodes move backward, or contrary to the order of signs, in the Ecliptic.

The time in which the Moon revolves from the Sun to the Sun again (or from change to change) is called a *Lunation*; which, according to Dr. Pound's mean measures, would always consist of 29 days 12 hours 44 minutes 3 seconds 2 thirds 58 fourths, if the motions of the Sun and Moon were always equable*.—Hence, 12 mean Lunations

* We have thought proper to keep by Dr. *Pound*'s length of a mean Lunation, because his numbers come nearer to the times of the antient Eclipses, than *Meyer*'s do, without allowing for the Moon's acceleration.

tions contain 354 days 8 hours 48 minutes 36 seconds 35 thirds 40 fourths, which is 10 days 21 hours 11 minutes 23 seconds 24 thirds 20 fourths less than the length of a common *Julian year*, consisting of 365 days 6 hours: and 13 mean Lunations contain 383 days 21 hours 32 minutes 39 seconds 38 thirds 38 fourths, which exceeds the length of a common *Julian year*, by 18 days 15 hours 32 minutes 39 seconds 38 thirds 38 fourths.

The mean time of New Moon being found for any given year and month, as suppose for *March* 1700, Old Stile, if this mean New Moon falls later than the 11th day of *March*, then, 12 mean Lunations added to the time of this mean New Moon, will give the time of the mean New Moon in *March* 1701, after having thrown off 365 days.— But, when the mean New Moon happens to be before the 11th of *March*, we must add 13 mean Lunations, in order to have the time of mean New Moon in *March* the year following: always taking care to subtract 365 days in common years, and 366 days in leap-years, from the sum of this addition.

Thus, *A. D.* 1700, Old Stile, the time of mean New Moon in *March* was the 8th day, at 16 hours 11 minutes 25 seconds after the noon of that day (*viz.* at 11 minutes 25 seconds past IV in the morning of the 9th day, according to common reckoning.) To this we must add 13 mean Lunations, or 383 days 21 hours 32 minutes 39 seconds 38 thirds 38 fourths, and the sum will be 392 days 13 hours 44 minutes 4 seconds 38 thirds 38 fourths; from which subtract 365 days, because the year 1701 is a common year, and there will remain 27 days 13 hours 44 minutes 4 seconds 38 thirds 38 fourths for the time of mean New Moon in *March*, *A. D.* 1701.

Carrying on this addition and subtraction till *A. D.* 1703, we find the time of mean New Moon in *March* that year, to be on the 6th day, at 7 hours 21 minutes 17 seconds 49 thirds 46 fourths past noon; to which add 13 mean Lunations, and the sum will be 390 days 4 hours 53 minutes 57 seconds 28 thirds 20 fourths; from which subtract 366 days, because the year 1704 is a leap-year, and there will remain 24 days 4 hours 53 minutes 57 seconds 28 thirds 20 fourths, for the time of mean New Moon in *March*, *A. D.* 1704.

In this manner was the first of the following Tables constructed to seconds, thirds and fourths; and then wrote out to the nearest seconds.—The reason why we chose to begin the year with *March*, was to avoid the inconvenience of adding a day to the tabular time in leap-years after *February*, or subtracting a day therefrom in *January* and *February* in those years; to which all tables of this kind are subject, which begin the year with *January*, in calculating the times of New or Full Moons.

The mean anomalies of the Sun and Moon, and the Sun's mean motion from the ascending Node of the Moon's Orbit, are set down in Table III. from one to 13 mean Lunations.—These Numbers, for 13 Lunations, being added to the radical anomalies of the Sun and Moon, and to the Sun's mean distance from the ascending Node, at the time of mean New Moon in *March* 1700, (Table I.) will give their mean anomalies, and the Sun's mean distance from the Node, at the time of mean New Moon in *March* 1701; and being added for 12 Lunations to those for 1701, give them for the time of mean New Moon in *March* 1702. And so on, as far as you please to continue the Table (which is here carried on to the year 1800) always throwing off 12 signs when their sum exceeds 12, and setting down the remainder as the proper quantity.

If the Numbers belonging to *A. D.* 1700 (in Table I.) be subtracted from those belonging to 1800, we shall have their whole differences in 100 compleat Julian years; which accordingly we find

to

to be 4 days 8 hours 10 minutes 52 seconds 15 thirds 40 fourths, with respect to the time of mean New Moon.—These being added together 60 times (always taking care to throw off a whole Lunation when the days exceed 29½) making up 60 centuries, or 6000 years, as in Table VI, which was carried on to seconds, thirds, and fourths; and then wrote out to the nearest seconds. In the same manner were the respective anomalies and the Sun's distance from the Node found, for these centurial years; and then (for want of room) wrote out only to the nearest minutes, which is sufficient in whole centuries.—By means of these two Tables, we may find the time of any mean New Moon in *March*, together with the anomalies of the Sun and Moon, and the Sun's distance from the Node, at these times, within the limits of 6000 years, either before or after any given year in the 18th century; and the mean time of any New or Full Moon in any given month after *March*, by means of the third and fourth Tables, within the same limits, as shewn in the precepts for calculation.

Thus it would be a very easy matter to calculate the time of any New or Full Moon, if the Sun and Moon moved equably in all parts of their Orbits.—But we have already shewn that their places are never the same as they would be by equable motions, except when they are in Apogee or Perigee; which is, when their mean anomalies are either nothing, or six signs: and that their mean places are always forwarder than their true places, whilst the anomaly is less than six signs; and their true places are forwarder than the mean, whilst the anomaly is more.

Hence it is evident, that whilst the Sun's anomaly is less than six signs, the Moon will overtake him, or be opposite to him, sooner than she could if his motion were equable; and later whilst his anomaly is more than six signs.—The greatest difference that can possibly happen between the mean and true time of New or Full Moon, on account of the inequality of the Sun's motion, is 3 hours 48 minutes 28 seconds: and that is, when the Sun's anomaly is either 3 signs 1 degree, or 8 signs 29 degrees; sooner in the first case, and later in the last.—In all other signs and degrees of anomaly, the difference is gradually less, and vanishes when the anomaly is either nothing or six signs.

The Sun is in his Apogee on the 30th of *June*, and in his Perigee on the 30th of *December*, in the present age: so that he is nearer the Earth in our winter than in our summer.—The proportional difference of distance, deduced from the difference of the Sun's apparent diameter at these times, is as 983 to 1017.

The Moon's orbit is dilated in winter, and contracted in summer; therefore, the Lunations are longer in winter than in summer. The greatest difference is found to be 22 minutes 29 seconds: the Lunations increasing gradually in length whilst the Sun is moving from his Apogee to his Perigee, and decreasing in length whilst he is moving from his Perigee to his Apogee.—On this account, the Moon will be later every time in coming to her conjunction with the Sun, or being in opposition to him, from *December* till *June*, and sooner from *June* till *December*, than if her orbit had continued of the same size all the year round.

As both these differences depend on the Sun's anomaly, they may be fitly put together into one Table, and called *The annual, or first equation of the mean to the true* * *syzygy* (see Table VII.) This equational difference is to be subtracted from the time of the mean syzygy when the Sun's anomaly is less than six signs, and added when the anomaly is more.—At the greatest, it is 4 hours 10 minutes 57 seconds, *viz.* 3 hours 48 minutes 28 seconds, on account of the Sun's unequal motion, and 22

* The word *syzygy* signifies both the conjunction and opposition of the Sun and Moon.

minutes

minutes 29 seconds, on account of the dilatation of the Moon's orbit.

This compound equation would be sufficient for reducing the mean time of New or Full Moon to the true time thereof, if the Moon's orbit were of a circular form, and her motion quite equable in it.—But the Moon's orbit is more elliptical than the Sun's, and her motion in it so much the more unequal. The difference is so great, that she is sometimes in conjunction with the Sun, or in opposition to him, sooner by 9 hours 47 minutes 54 seconds, than she would be if her motion were equable; and at other times as much later.—The former happens when her mean anomaly is 9 signs 4 degrees, and the latter when it is 2 signs 26 degrees. *See* Table IX.

At different distances of the Sun from the Moon's Apogee, the figure of the Moon's orbit becomes different.—It is longest of all, or most excentric, when the Sun is in the same sign and degree either with the Moon's Apogee or Perigee; shortest of all, or least excentric, when the Sun's distance from the Moon's Apogee is either three signs or nine signs; and at a mean state when the distance is either 1 sign 15 degrees, 4 signs 15 degrees, 7 signs 15 degrees, or 10 signs 15 degrees.—When the Moon's orbit is at it's greatest excentricity, her apogeal distance from the Earth's center is to her perigeal distance therefrom, as 1067 is to 933; when least excentric, as 1043 is to 957; and when at the mean state, as 1055 is to 945.

But the Sun's distance from the Moon's Apogee is equal to the quantity of the Moon's mean anomaly at the time of New Moon, and by the addition of six signs, it becomes equal in quantity to the Moon's mean anomaly at the time of Full Moon.—Therefore, a table may be constructed so as to answer to all the various inequalities depending on the different excentricities of the Moon's orbit, in the syzygies; and called *The second equation of the*

the mean to the true syzygy (see Table IX.) and the Moon's anomaly, when equated by Table VIII. may be made the proper argument for taking out this second equation of time; which must be added to the former equated time, when the Moon's anomaly is less than six signs, and subtracted when the anomaly is more.

There are several other inequalities in the Moon's motion, which sometimes bring on the true syzygy a little sooner, and at other times keep it back a little later, than it would otherwise be: but they are so small, that they may be all omitted except two; the former of which (*see* Table X.) depends on the difference between the anomalies of the Sun and Moon in the syzygies, and the latter (*see* Table XI.) depends on the Sun's distance from the Moon's Nodes at these times.—The greatest difference arising from the former, is 4 minutes 58 seconds; and from the latter, 1 minute 34 seconds.

Having described the Phenomena arising from the inequalities of the Solar and Lunar Motions, we shall now shew the reasons of these inequalities.

In all calculations relating to the Sun and Moon, we consider the Sun as a moving body, and the Earth as a body at rest; since all the appearances are the same, whether it be the Sun or the Earth that moves.—But the truth is, that the Sun is at rest, and the Earth moves round him once a year, in the plane of the Ecliptic. Therefore, whatever sign and degree of the Ecliptic the Earth is in, at any given time, the Sun will then appear to be in the opposite sign and degree.

The nearer that any body is to the Sun, the more it is attracted by him; and this attraction increases as the square of the distance diminishes; and *vice versâ*.

The Earth's annual Orbit is elliptical, and the Sun is placed in one of it's focuses. The remotest

point

point of the Earth's orbit from the Sun, is called *The Earth's Aphelion*; and the nearest point of the Earth's orbit to the Sun, is called *The Earth's Perihelion.*—When the Earth is in it's Aphelion, the Sun appears to be in it's Apogee; and when the Earth is in it's Perihelion, the Sun appears to be in it's Perigee.

As the Earth moves from it's Aphelion to it's Perihelion, it is constantly more and more attracted by the Sun; and this attraction, by conspiring in some degree with the Earth's motion, must necessarily accelerate it. But as the Earth moves from it's Perihelion to it's Aphelion, it is continually less and less attracted by the Sun; and as this attraction acts then just as much against the Earth's motion, as it acted for it in the other half of the Orbit, it retards the motion in the like degree.—The faster the Earth moves, the faster will the Sun appear to move; the slower the Earth moves, the slower is the Sun's apparent motion.

The Moon's orbit is also elliptical, and the Earth keeps constantly in one of it's focuses.—The Earth's attraction has the same kind of influence on the Moon's motion, as the Sun's attraction has on the motion of the Earth: and therefore, the Moon's motion must be continually accelerated whilst she is passing from her Apogee to her Perigee; and as gradually retarded in moving from her Perigee to her Apogee.

At the time of New Moon, the Moon is nearer the Sun than the Earth is at that time, by the whole semidiameter of the Moon's orbit; which, at a mean state, is 240,000 miles: and at the Full, she is as much farther from the Sun than the Earth then is.—Consequently, the Sun attracts the Moon more than it attracts the Earth in the former case, and less in the latter. The difference is greatest when the Earth is nearest the Sun, and least when it is farthest from him. The obvious result of this is, that as the Earth is nearest to the Sun in winter, and fartheſt from him in ſummer, the Moon's orbit muſt be dilated in winter, and contracted in ſummer.

Theſe are the principal cauſes of the difference of time, that generally happens between the mean and true times of conjunction or oppoſition of the Sun and Moon. As to the other two differences, *viz.* thoſe which depend on the difference between the anomalies of the Sun and Moon, and upon the Sun's diſtance from the lunar Nodes, in the ſyzygies, they are owing to the different degrees of attraction of the Sun and Earth upon the Moon, at greater or leſs diſtances, according to their reſpective anomalies, and to the poſition of the Moon's Nodes with reſpect to the Sun.

If ever it ſhould happen, that the anomalies of both the Sun and Moon were either nothing or ſix ſigns, at the mean time of New or Full Moon, and the Sun ſhould then be in conjunction with either of the Moon's Nodes, all the above-mentioned equations would vaniſh, and the mean and true time of the ſyzygy would coincide. But if ever this circumſtance did happen, we cannot expect the like again in many ages afterward.

TABLE

TABLE I. *The mean Time of New Moon in* March, *Old Stile; with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Moon's Ascending Node, from* A. D. 1700 *to* A. D. 1800 *inclusive.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
1700	8	16	11	27	8	19	58	48	1	22	30	37	6	14	31	7
1701	27	13	44	5	9	8	20	59	0	28	7	42	7	23	14	8
1702	16	22	32	41	8	27	36	51	11	7	55	47	8	1	10	55
1703	6	7	21	18	8	16	52	43	9	17	43	52	8	9	19	42
1704	24	4	53	57	9	5	14	54	8	23	20	57	9	18	2	43
1705	13	13	42	30	8	24	30	4[illegible]	7	3	9	2	9	26	5	30
1706	2	22	31	11	8	13	46	39	5	12	57	7	10	4	8	17
1707	21	20	3	50	9	2	8	5[illegible]	4	18	34	13	11	12	51	18
1708	10	4	52	27	8	21	24	43	2	28	22	18	11	20	54	5
1709	29	2	25	7	9	9	46	54	2	3	59	24	0	29	37	6
1710	18	11	13	43	8	29	2	47	0	13	47	30	1	7	39	54
1711	7	20	2	20	8	18	18	39	10	23	35	36	1	15	42	41
1712	25	17	34	59	9	6	40	51	9	29	12	42	2	14	25	43
1713	15	2	23	36	8	25	56	43	8	9	0	47	3	2	28	3[illegible]
1714	4	11	12	13	8	15	12	35	6	18	48	52	3	10	31	1
1715	23	8	44	52	9	3	34	47	5	24	25	57	4	19	14	18
1716	11	17	33	29	8	22	50	39	4	4	14	2	4	27	17	5
1717	1	2	22	5	8	12	6	37	2	14	2	8	5	5	19	52
1718	19	23	54	45	9	0	28	44	1	19	39	13	6	14	2	5
1719	9	8	43	22	8	19	44	37	11	29	27	18	6	22	5	41
1720	27	6	16	1	9	8	6	49	11	5	4	24	8	0	48	42
1721	16	15	4	38	8	27	22	41	9	14	52	29	8	8	51	29
1722	5	23	53	14	8	16	38	33	7	24	40	34	8	16	54	16
1723	24	21	25	54	9	5	0	45	7	0	17	40	9	25	37	18
1724	13	6	14	31	8	24	16	37	5	10	5	45	10	3	40	5
1725	2	15	3	7	8	13	32	29	3	19	53	50	10	11	42	52
1726	21	12	35	47	9	1	54	41	2	25	30	56	11	20	25	5[illegible]
1727	10	21	24	23	8	21	10	34	1	5	19	1	11	28	28	41
1728	28	18	57	3	9	9	52	4	0	10	56	7	1	7	11	42
1729	18	3	45	40	8	28	48	39	10	20	44	12	1	15	14	29
1730	7	12	34	16	8	18	4	31	9	0	32	17	1	23	17	16
1731	26	10	6	56	9	6	26	42	8	6	9	23	3	2	0	17
1732	14	18	55	3[illegible]	8	25	42	34	6	15	57	[illegible]	3	10	3	4

TABLE

TABLE I. *continued.* *Old Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	o	′	″	s	o	′	″	s	o	′	″
1733	4	3	44	9	8	14	58	26	4	25	45	33	3	18	5	5
1734	23	1	16	49	9	3	20	38	4	1	22	39	4	26	48	5
1735	12	10	5	25	8	22	36	30	2	11	10	44	5	4	51	4
1736	0	18	54	2	8	11	52	22	0	20	58	49	5	12	54	2
1737	19	16	26	42	9	0	14	34	11	26	35	55	6	21	37	2
1738	9	1	15	18	8	19	30	26	10	6	24	0	6	29	40	1
1739	27	22	47	58	9	7	52	38	9	12	1	6	8	8	23	1
1740	16	7	36	34	8	27	8	30	7	21	49	11	8	16	26	[illegible]
1741	5	16	25	11	8	16	24	22	6	1	37	16	8	24	28	5
1742	24	13	57	52	9	4	46	34	5	7	14	22	10	3	11	5
1743	13	22	46	27	8	24	2	27	3	17	2	27	10	1	14	41
1744	2	7	35	4	8	13	18	20	1	26	50	32	10	19	17	2
1745	21	5	7	44	9	1	40	32	1	2	27	38	11	28	0	3
1746	10	13	56	20	8	20	56	24	11	12	15	43	0	6	3	17
1747	29	11	29	0	9	9	18	36	10	17	52	49	1	14	46	1
1748	17	20	17	36	8	28	34	28	8	27	40	54	1	22	49	5
1749	7	5	6	13	8	17	50	20	7	7	28	59	2	0	51	5
1750	26	2	38	53	9	6	12	32	6	13	6	5	3	9	34	53
1751	15	11	27	29	8	25	28	24	4	22	54	10	3	17	37	4
1752	3	20	16	6	8	14	44	16	3	2	42	15	3	25	40	27
1753	22	17	48	45	9	3	6	28	2	8	19	21	5	4	23	28
1754	12	2	37	22	8	22	22	20	0	18	7	26	5	12	26	15
1755	1	11	25	59	8	11	38	12	10	27	55	31	5	20	29	2
1756	19	8	58	38	9	0	0	24	10	3	32	37	6	29	12	3
1757	8	17	47	15	8	19	16	16	8	13	20	42	7	7	14	5
1758	27	15	19	54	9	7	38	28	7	18	57	48	8	15	57	5
1759	17	0	8	31	8	26	54	20	5	28	45	54	8	24	0	39
1760	5	8	57	8	8	16	10	12	4	8	34	0	9	2	3	26
1761	24	6	29	47	9	4	32	24	3	14	11	6	10	10	46	27
1762	13	15	18	24	8	23	48	16	1	23	59	11	10	18	49	14
1763	3	0	7	1	8	13	4	8	0	3	47	16	10	26	52	1
1764	20	21	39	40	9	1	26	20	11	9	24	21	0	5	35	2
1765	10	6	28	17	8	20	42	13	9	19	12	26	0	13	37	4
1766	29	4	0	56	9	9	4	20	8	24	49	32	1	22	20	5

TABLE

TABLE I. *concluded.* *Old Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Diff. from the Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
1767	18	12	49	33	8	28	20	17	7	4	37	37	2	0	23	38
1768	6	21	38	10	8	17	36	9	5	14	25	42	2	8	26	25
1769	25	19	10	40	9	5	58	21	4	20	2	48	3	17	9	27
1770	15	3	59	26	8	25	14	13	2	29	50	53	3	25	12	14
1771	4	12	48	2	8	14	30	5	1	9	38	58	4	3	15	1
1772	22	10	20	4	9	2	52	17	0	15	16	4	5	11	58	3
1773	11	19	9	19	8	22	8	9	10	25	4	9	5	20	0	5
1774	1	3	57	55	8	11	24	1	9	4	52	1	5	28	3	37
1775	20	1	30	35	8	29	46	13	8	10	29	20	7	6	40	3
1776	8	10	19	12	8	19	2	5	6	20	17	25	7	14	49	25
1777	27	7	51	51	9	7	24	17	5	25	54	31	8	23	32	26
1778	16	16	40	2	8	26	40	9	4	5	42	36	9	1	35	13
1779	6	1	29	4	8	15	56	1	2	15	30	41	9	9	38	0
1780	23	23	1	44	9	4	18	13	1	21	7	47	10	18	21	1
1781	13	7	50	21	8	23	34	5	0	0	55	52	10	26	23	48
1782	2	16	38	57	8	12	49	58	10	10	43	5	11	4	26	35
1783	21	14	11	37	9	1	12	10	9	16	21	3	0	13	9	36
1784	9	23	0	13	8	20	28	3	7	26	9	8	0	21	12	23
1785	28	20	32	53	9	8	50	15	7	1	46	14	1	29	55	25
1786	18	5	21	30	8	28	6	7	5	11	34	19	2	7	58	12
1787	7	14	10	6	8	17	21	59	3	21	22	24	2	16	0	59
1788	25	11	42	46	9	5	44	11	2	26	59	30	3	24	44	1
1789	14	20	31	23	8	25	0	3	1	6	47	35	4	2	46	48
1790	4	5	19	59	8	14	15	55	11	16	35	40	4	10	49	35
1791	23	2	52	39	9	2	38	7	10	22	12	46	5	19	32	37
1792	11	11	41	15	8	21	53	59	9	2	0	52	5	27	35	24
1793	30	9	13	55	9	10	16	11	8	7	37	58	7	6	18	26
1794	19	18	2	32	8	29	32	3	6	17	26	4	7	14	21	13
1795	9	2	51	8	8	18	47	55	4	27	14	9	7	22	24	0
1796	27	0	23	48	9	7	10	7	4	2	51	14	9	1	7	1
1797	16	9	12	24	8	26	25	59	2	12	39	19	9	9	9	48
1798	5	18	1	1	8	15	41	51	0	22	27	25	9	17	12	35
1799	24	15	33	41	9	4	4	3	11	28	4	51	10	25	55	37
1800	13	0	22	17	8	23	19	55	10	7	52	36	11	3	58	2

TABLE

TABLE II. *Mean New Moon, &c. in* March, *New Stile, from* A. D. 1752 *to* A. D. 1800.

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	'	"	s	°	'	"	s	°	'	"
1752	14	20	16	6	8	14	44	16	3	2	42	15	3	25	40	27
1753	4	5	4	42	8	4	0	8	1	12	30	20	4	3	43	14
1754	23	2	37	22	8	22	22	20	0	18	7	26	5	12	26	15
1755	12	11	25	59	8	11	38	12	10	27	55	31	5	20	29	2
1756	30	8	58	3	9	0	0	24	10	3	32	37	6	29	12	3
1757	19	17	47	15	8	19	16	16	8	13	20	42	7	7	14	50
1758	9	2	35	51	8	8	32	8	6	23	8	47	7	15	17	38
1759	28	0	8	31	8	26	54	20	5	28	45	54	8	24	0	39
1760	16	8	57	8	8	16	10	12	4	8	34	0	9	2	3	26
1761	5	17	45	44	8	5	26	4	2	18	22	5	9	10	6	13
1762	24	15	18	24	8	23	48	16	1	23	59	11	10	18	49	14
1763	14	0	7	1	8	13	4	8	0	3	47	16	10	26	52	1
1764	2	8	55	36	8	2	20	0	10	13	35	21	11	4	54	48
1765	21	6	28	[illegible]	8	20	42	13	9	19	12	26	0	13	37	49
1766	10	15	16	53	8	9	58	5	7	29	0	31	0	21	40	37
1767	29	12	49	33	8	28	20	17	7	4	37	37	2	0	23	38
1768	17	21	38	9	8	17	36	9	5	14	25	42	2	8	26	25
1769	7	6	26	46	8	6	52	1	3	24	13	47	2	16	29	13
1770	26	3	59	26	8	25	14	13	2	29	50	53	3	25	12	14
1771	15	12	48	2	8	14	30	5	1	9	38	58	5	3	15	1
1772	3	21	36	39	8	3	45	57	11	17	27	3	4	11	17	48
1773	22	19	9	19	8	22	8	9	10	25	4	9	5	20	0	50
1774	12	3	57	55	8	11	24	1	9	4	52	14	5	28	3	37
1775	1	12	46	31	8	0	39	53	7	14	40	19	6	6	6	24
1776	19	10	19	12	8	19	2	5	6	20	17	25	7	14	49	25
1777	8	19	7	48	8	8	17	57	5	0	5	30	7	22	52	12
1778	27	16	40	28	8	26	40	9	4	5	42	36	9	1	35	13
1779	17	1	29	4	8	15	56	1	2	15	30	41	9	9	38	0
1780	5	10	17	40	8	5	11	53	0	25	18	46	9	17	40	47
1781	24	7	50	21	8	23	34	5	0	0	55	52	10	26	23	48
1782	13	16	38	57	8	12	49	58	10	10	43	57	11	4	26	35
1783	3	1	27	33	8	2	5	50	8	20	32	2	11	12	29	22
1784	20	23	0	13	8	20	28	3	9	26	9	8	0	21	12	23
1785	10	7	48	50	8	9	43	55	6	5	57	13	0	29	15	10
1786	9	5	21	30	8	28	6	7	5	11	34	19	2	7	58	12

TABLE

TABLE II. *concluded. New Stile.*

Y. of Chr.	Mean New Moon in March.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
1787	18	14	10	6	8	17	21	59	3	21	22	24	2	16	0	59
1788	6	22	58	42	8	6	37	51	2	1	10	29	2	24	3	46
1789	25	20	31	23	8	25	0	3	1	6	47	35	4	2	46	48
1790	15	5	19	59	8	14	15	55	11	16	35	40	4	10	49	35
1791	4	14	8	35	8	3	31	47	9	26	23	45	4	18	52	22
1792	22	11	41	15	8	21	53	59	9	2	0	52	5	27	35	24
1793	11	20	29	51	8	11	9	51	7	11	48	57	6	5	38	11
1794	30	18	2	32	8	29	32	3	6	17	26	4	7	14	21	13
1795	20	2	51	8	8	18	47	55	4	27	14	9	7	22	24	0
1796	8	11	39	44	8	8	3	47	3	7	2	14	8	0	26	47
1797	27	9	12	24	8	26	25	59	2	12	39	19	9	9	9	48
1798	16	18	1	1	8	15	41	51	0	22	27	25	9	17	12	35
1799	6	2	49	37	8	4	57	43	11	2	15	30	9	25	15	22
1800	25	0	22	17	8	23	19	55	10	7	52	36	11	3	58	24

TABLE III. *Mean Anomalies, and Sun's mean Distance from the Node, for 13½ mean Lunations.*

N°	Mean Lunations.				Sun's mean Anomaly.				Moon's mean Anomaly.				Sun's mean Dist. from the Node.			
	D.	H.	M.	S.	s	°	′	″	s	°	′	″	s	°	′	″
1	29	12	44	3	0	29	6	19	0	25	49	0	1	0	40	14
2	59	1	28	6	1	28	12	39	1	21	38	1	2	1	20	28
3	88	14	12	9	2	27	18	58	2	17	27	1	3	2	0	42
4	118	2	56	12	3	26	25	17	3	13	16	2	4	2	40	56
5	147	15	40	15	4	25	31	37	4	9	5	2	5	3	21	10
6	177	4	24	18	5	24	37	56	5	4	54	3	6	4	1	24
7	206	17	8	21	6	23	44	15	6	0	43	3	7	4	41	38
8	236	5	52	24	7	22	50	35	6	26	32	3	8	5	21	52
9	265	18	36	27	8	21	56	54	7	22	21	4	9	6	2	6
10	295	7	20	30	9	21	3	14	8	18	10	4	10	6	42	20
11	324	20	4	33	10	20	9	33	9	13	59	5	11	7	22	34
12	354	8	48	36	11	19	15	52	10	9	48	5	0	8	2	47
13	383	21	32	40	0	18	22	12	11	5	37	6	1	8	43	1
½	14	18	22	2	0	14	33	10	6	12	54	20	0	15	20	7

TABLE IV. *The Days of the Year, reckoned from the beginning of* March.

Days.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.
1	1	32	62	93	123	154	185	215	246	276	307	338
2	2	33	63	94	124	155	186	216	247	277	308	339
3	3	34	64	95	125	156	187	217	248	278	309	340
4	4	35	65	96	126	157	188	218	249	279	310	341
5	5	36	66	97	127	158	189	219	250	280	311	342
6	6	37	67	98	128	159	190	220	251	281	312	343
7	7	38	68	99	129	160	191	221	252	282	313	344
8	8	39	69	100	130	161	192	222	253	283	314	345
9	9	40	70	101	131	162	193	223	254	284	315	346
10	10	41	71	102	132	163	194	224	255	285	316	347
11	11	42	72	103	133	164	195	225	256	286	317	348
12	12	43	73	104	134	165	196	226	257	287	318	349
13	13	44	74	105	135	166	197	227	258	288	319	350
14	14	45	75	106	136	167	198	228	259	289	320	351
15	15	46	76	107	137	168	199	229	260	290	321	352
16	16	47	77	108	138	169	200	230	261	291	322	353
17	17	48	78	109	139	170	201	231	262	292	323	354
18	18	49	79	110	140	171	202	232	263	293	324	355
19	19	50	80	111	141	172	203	233	264	294	325	356
20	20	51	81	112	142	173	204	234	265	295	326	357
21	21	52	82	113	143	174	205	235	266	296	327	358
22	22	53	83	114	144	175	206	236	267	297	328	359
23	23	54	84	115	145	176	207	237	268	298	329	360
24	24	55	85	116	146	177	208	238	269	299	330	361
25	25	56	86	117	147	178	209	239	270	300	331	362
26	26	57	87	118	148	179	210	240	271	301	332	363
27	27	58	88	119	149	180	211	241	272	302	333	364
28	28	59	89	120	150	181	212	242	273	303	334	365
29	29	60	90	121	151	182	213	243	274	304	335	366
30	30	61	91	122	152	183	214	244	275	305	336	
31	31		92		153	184		245		306	337	

TABLE

TABLE V. *Mean Lunations from* 1 *to* 100000.

Lunat.	Days. Decimal Parts.		Days	Hou.	M.	S.	Th.	Fo.
1	29.530590851080	=	29	12	44	3	2	58
2	59.061181702160		59	1	28	6	5	57
3	88.591772553240		88	14	12	9	8	55
4	118.122363404320		118	2	56	12	11	53
5	147.652954255401		147	15	40	15	14	52
6	177.183545106481		177	4	24	18	17	50
7	206.714135957561		206	17	8	21	20	48
8	236.244726808641		236	5	52	24	23	47
9	265.775317659722		265	18	36	27	26	45
10	295.30590851080		295	7	20	30	29	43
20	590.61181702160		590	14	41	0	59	26
30	885.91772553240		885	22	1	31	29	10
40	1181.22363404320		1181	5	22	1	58	53
50	1476.52954255401		1476	12	42	32	28	36
60	1771.83545106481		1771	20	3	2	58	19
70	2067.14135957561		2067	3	23	33	28	2
80	2362.44726808641		2362	10	44	3	57	46
90	2657.75317659722		2657	18	4	34	27	29
100	2953.0590851080		2953	1	25	4	57	12
200	5906.1181702160		5906	2	50	9	54	24
300	8859.1772553240		8859	4	15	14	51	36
400	11812.2363404320		11812	5	40	19	48	48
500	14765.2954255401		14765	7	5	24	46	0
600	17718.3545106481		17718	8	30	29	43	12
700	20671.4135957561		20671	9	55	34	40	24
800	23624.4726808641		23624	11	20	39	37	36
900	26577.5317659722		26577	12	45	44	34	48
1000	29530.590851080		29530	14	10	49	32	0
2000	59061.181702160		59061	4	21	39	4	0
3000	88591.772553240		88591	18	32	28	36	0
4000	118122.363404320		118122	8	43	18	8	0
5000	147652.954255401		147652	22	54	7	40	0
6000	177183.545106481		177183	13	4	57	12	0
7000	206714.135957561		206714	3	15	46	44	0
8000	236244.726808641		236244	17	26	36	16	0
9000	265775.317659722		265775	7	37	25	48	0
10000	295305.90851080		295305	21	48	15	20	0
20000	590611.81702160		590611	19	36	30	40	0
30000	885917.72553240		885917	17	24	46	0	0
40000	1181223.63404320		1181223	15	13	1	20	0
50000	1476529.54255401		1476529	13	1	16	40	0
60000	1771835.45106481		1771835	10	49	32	0	0
70000	2067141.35957561		2067141	8	37	47	20	0
80000	2362447.26808641		2362447	6	25	2	40	0
90000	2657753.17659722		2657753	4	14	18	0	0
100000	2953059.0851080		2953059	2	2	33	20	0

TABLE VI. *The first mean New Moon, with the mean Anomalies of the Sun and Moon, and the Sun's mean Distance from the Ascending Node, next after compleat Centuries of Julian years.*

Lunations.	Julian years.	First New Moon.				Sun's mean Anomaly.			Moon's mean Anomaly.			Sun from Node.		
		D.	H.	M.	S.	s	°	′	s	°	′	s	°	′
1237	100	4	8	10	52	0	3	21	8	15	22	4	19	27
2474	200	8	16	21	44	0	6	42	5	0	44	9	8	55
3711	300	13	0	32	37	0	10	3	1	16	6	1	28	22
4948	400	17	8	43	29	0	13	24	10	1	28	6	17	49
6185	500	21	16	54	21	0	16	46	6	16	50	11	7	16
7422	600	26	1	5	14	0	20	7	3	2	12	3	26	44
86[illegible]	700	0	20	32	3	11	24	22	10	21	45	7	15	31
989[illegible]	800	5	4	42	55	11	27	43	7	7	7	0	4	58
11132	900	9	12	53	47	0	1	4	3	22	29	4	24	25
12369	1000	13	21	4	40	0	4	25	0	7	51	9	13	53
13606	1100	18	5	15	32	0	7	46	8	23	13	2	3	20
14843	1200	22	13	26	24	0	11	7	5	8	35	6	22	47
16080	1300	26	21	37	16	0	14	28	1	23	57	11	12	15
17316	1400	1	17	4	6	11	18	43	9	13	30	3	1	2
18553	1500	6	1	14	58	11	22	4	5	28	52	7	20	29
19790	1600	10	9	25	50	11	25	25	2	14	14	0	9	56
21027	1700	14	17	36	42	11	28	46	10	29	36	4	29	23
22264	1800	19	1	47	35	0	2	8	7	14	58	9	18	51
23501	1900	23	9	58	27	0	5	29	4	0	20	2	8	18
24738	2000	27	18	9	19	0	8	50	0	15	42	6	27	45
25974	2100	2	13	36	8	11	13	5	8	5	15	10	16	32
27211	2200	6	21	47	1	11	16	26	4	20	37	3	6	0
28448	2300	11	5	57	53	11	19	47	1	5	59	7	25	27
29685	2400	15	14	8	45	11	23	8	9	21	21	0	14	54
30922	2500	19	22	19	38	11	26	29	6	6	43	5	4	22
32159	2600	24	6	30	30	11	29	50	2	22	4	9	23	49
33396	2700	28	14	41	22	0	3	11	11	7	26	2	13	16
34632	2800	3	10	8	11	11	7	26	6	26	59	6	2	3
35869	2900	7	18	19	3	11	10	47	3	12	21	10	21	30
37106	3000	12	2	29	56	11	14	8	11	27	43	3	10	58
38343	3100	16	10	40	48	11	17	30	8	13	5	8	0	25
39580	[illegible]	20	18	51	40	11	20	51	4	28	27	0	19	52

TABLE

TABLE VI. *concluded.*

Lunations.	Julian years.	First New Moon. D.	H.	M.	S.	Sun's mean Anomaly. s	°	′	Moon's mean Anomaly. s	°	′	Sun's mean Dist. from Node. s	°	′
40817	3300	25	3	2	33	11	24	12	1	13	49	5	9	20
42054	3400	29	11	13	25	11	27	33	9	29	11	9	28	47
43290	3500	4	6	40	14	11	1	48	5	18	44	1	17	34
44527	3600	8	14	51	6	11	5	9	2	4	6	6	7	1
45764	3700	12	23	1	59	11	8	30	10	19	28	10	26	29
47001	3800	17	7	12	51	11	11	51	7	4	50	3	15	56
48238	3900	21	15	23	43	11	15	12	3	20	12	8	5	23
49475	4000	25	23	34	35	11	18	33	0	5	34	0	24	50
50711	4100	0	19	1	25	10	22	48	7	25	7	4	13	37
51948	4200	5	3	12	17	10	26	9	4	10	29	9	3	5
53185	4300	9	11	23	9	10	29	31	0	25	51	1	22	32
54422	4400	13	19	34	1	11	2	52	9	11	13	6	11	59
55659	4500	18	3	44	54	11	6	13	5	26	35	11	1	27
56896	4600	22	11	55	46	11	9	34	2	11	57	3	20	54
58133	4700	26	20	6	38	11	12	55	10	27	19	8	10	21
59369	4800	1	15	33	27	10	17	9	6	16	52	11	29	8
60606	4900	5	23	44	20	10	20	31	3	2	14	4	18	36
61843	5000	10	7	55	12	10	23	52	11	17	36	9	8	3
63080	5100	14	16	6	4	10	27	13	8	2	58	1	27	30
64317	5200	19	0	16	56	11	0	34	4	18	20	6	16	57
65554	5300	23	8	27	49	11	3	55	1	3	42	11	6	25
66791	5400	27	16	38	41	11	7	16	9	19	4	2	25	52
68028	5500	2	12	5	30	10	11	31	5	8	37	7	14	39
69265	5600	6	20	16	22	10	14	52	1	23	59	0	4	6
70502	5700	11	4	27	15	10	18	14	10	9	21	4	23	34
71739	5800	15	12	38	7	10	21	35	6	24	43	9	13	1
72976	5900	19	20	48	59	10	24	56	3	10	5	2	2	28
74212	6000	24	4	59	52	10	28	17	11	25	27	6	21	[illegible]

If Dr. *Pound*'s mean Lunation (which we have kept by in making these Tables) be added 74212 times to itſelf, the ſum will amount to 6000 Julian years 24 days 4 hours 59 minutes 51 ſeconds 40 thirds; agreeing with the firſt part of the laſt line of this Table, within half a ſecond

TABLE VII. *The annual, or first Equation of the mean to the true Syzygy.*

Argument. Sun's mean Anomaly

Subtract.

Degrees	0 Signs H. M. S.	1 Sign H. M. S.	2 Signs H. M. S.	3 Signs H. M. S.	4 Signs H. M. S.	5 Signs H. M. S.	Degrees
0	0 0 0	2 3 12	3 35 0	4 10 53	3 39 30	2 7 45	30
1	0 4 18	2 6 55	3 37 10	4 10 57	3 37 19	2 3 55	29
2	0 8 35	2 10 36	3 39 18	4 10 55	3 35 6	2 0 1	28
3	0 12 5[illegible]	2 14 15	3 41 23	4 10 49	3 32 50	1 56 5	27
4	0 17 8	2 17 52	3 43 26	4 10 39	3 30 30	1 52 6	26
5	0 21 24	2 21 27	3 45 25	4 10 24	3 28 5	1 48 4	25
6	0 25 39	2 25 9	3 47 19	4 10 4	3 25 35	1 41 1	24
7	0 28 55	2 28 29	3 49 7	4 9 39	3 23 0	1 39 56	23
8	0 34 11	2 31 57	3 50 50	4 9 10	3 20 20	1 35 49	22
9	0 38 26	2 35 22	3 52 29	4 8 37	3 17 35	1 31 41	21
10	0 42 39	2 38 44	4 54 4	4 7 59	3 14 49	1 27 31	20
11	0 46 52	2 42 3	3 55 35	4 7 16	3 11 59	1 23 19	19
12	0 51 4	2 45 18	3 57 2	4 6 29	3 9 6	1 19 5	18
13	0 55 17	2 48 30	3 58 27	4 5 37	3 6 10	1 14 49	17
14	0 59 27	2 51 40	3 59 49	4 4 41	3 3 1[illegible]	1 10 32	16
15	1 3 36	2 54 48	3 1 7	4 3 40	3 0 7	1 6 15	15
16	1 7 45	2 57 53	4 2 18	4 2 35	2 57 [illegible]	1 1 56	14
17	1 11 53	3 0 54	4 3 23	4 1 26	2 53 49	0 57 36	13
18	1 16 0	3 3 51	4 4 22	4 0 12	2 50 36	0 53 15	12
19	1 20 6	3 6 45	4 5 18	3 58 52	2 47 18	0 48 52	11
20	1 24 10	3 9 36	4 6 10	3 57 27	2 43 57	0 44 28	10
21	1 28 12	3 12 24	4 6 58	3 55 59	2 40 33	0 40 2	9
22	1 32 12	3 15 9	4 7 41	3 54 26	2 37 6	0 35 36	8
23	1 36 10	3 17 51	4 8 21	3 52 49	2 33 3	0 31 10	7
24	1 40 6	3 20 30	4 8 57	3 51 9	2 30 2	0 26 44	6
25	1 44 1	3 23 5	4 9 29	3 49 26	2 26 26	0 22 17	5
26	1 47 5[illegible]	3 25 36	4 9 55	3 47 38	2 22 47	0 17 50	4
27	1 51 46	3 28 3	4 10 16	3 45 44	2 19 [illegible]	0 13 23	3
28	1 55 3[illegible]	3 30 26	4 10 33	3 43 45	2 15 2[illegible]	0 8 56	2
29	1 59 26	3 32 45	4 10 45	3 41 40	2 11 35	0 4 29	1
30	2 3 12	3 35 0	4 10 53	3 39 30	2 7 45	0 0 0	0
	11 Signs	10 Signs	9 Signs	8 Signs	7 Signs	6 Signs	Deg.

Add

TABLE

TABLE VIII. *Equation of the Moon's mean Anomaly.*

Argument. Sun's mean Anomaly.

Subtract

Degrees	0 Signs	1 Sign	2 Signs	3 Signs	4 Signs	5 Signs	Degrees
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
0	0 0 0	0 46 45	1 21 32	1 35 1	1 23 4	0 48 19	30
1	0 1 37	0 48 10	1 22 21	1 35 2	1 22 14	0 46 51	29
2	0 3 13	0 49 34	1 23 10	1 35 1	1 21 24	0 45 23	28
3	0 4 52	0 50 53	1 23 57	1 35 0	1 20 32	0 43 54	27
4	0 6 28	0 52 19	1 24 41	1 34 57	1 19 38	0 42 24	26
5	0 8 6	0 53 40	1 25 24	1 34 50	1 18 42	0 40 53	25
6	0 9 42	0 55 0	1 26 6	1 34 43	1 17 45	0 39 21	24
7	0 11 20	0 56 21	1 26 48	1 34 33	1 16 48	0 37 49	23
8	0 12 56	0 57 38	1 27 28	1 34 22	1 15 47	0 36 15	22
9	0 14 33	0 58 56	1 28 6	1 34 9	1 14 44	0 34 40	21
10	0 16 10	1 0 13	1 28 43	1 33 53	1 13 41	0 33 5	20
11	0 17 47	1 1 29	1 29 17	1 33 37	1 12 37	0 31 31	19
12	0 19 23	1 2 43	1 29 51	1 33 20	1 11 33	0 29 54	18
13	0 20 59	1 3 56	1 30 22	1 33 0	1 10 26	0 28 18	17
14	0 22 35	1 5 8	1 30 50	1 32 38	1 9 17	0 26 40	16
15	0 24 10	1 6 18	1 31 19	1 32 14	1 8 8	0 25 3	15
16	0 25 45	1 7 27	1 31 45	1 31 50	1 6 58	0 23 23	14
17	0 27 19	1 8 36	1 32 12	1 31 23	1 5 46	0 21 45	13
18	0 28 52	1 9 42	1 32 34	1 30 55	1 4 32	0 20 7	12
19	0 30 25	1 10 49	1 32 57	1 30 25	1 3 19	0 18 28	11
20	0 31 57	1 11 54	1 33 17	1 29 54	1 2 1	0 16 48	10
21	0 33 29	1 12 58	1 33 36	1 29 20	1 0 45	0 15 8	9
22	0 35 2	1 14 1	1 33 52	1 28 45	0 59 26	0 13 28	8
23	0 36 32	1 15 1	1 34 6	1 28 9	0 58 7	0 11 48	7
24	0 38 1	1 16 0	1 34 18	1 27 30	0 56 45	0 10 7	6
25	0 39 29	1 16 59	1 34 30	1 26 50	0 55 23	0 8 20	5
26	0 40 59	1 17 57	1 34 49	1 26 27	0 54 1	0 6 44	4
27	0 42 26	1 18 52	1 34 48	1 25 5	0 52 37	0 5 3	3
28	0 43 54	1 19 47	1 34 54	1 24 39	0 51 12	0 3 21	2
29	0 45 19	1 20 40	1 34 58	1 23 52	0 49 45	0 1 40	1
30	0 46 45	1 21 32	1 35 1	1 23 4	0 48 19	0 0 0	0
Deg	11 Signs	10 Signs	9 Signs	8 Signs	7 Signs	6 Signs	Deg

Add

TABLE X. *The third Equation of the mean to the true Syzygy.*

Argument. Sun's Anomaly.—Moon's Anomaly

Degrees	Signs 0 Sub. 6 Add M.	S.	Signs 1 Sub. 7 Add M.	S.	Signs 2 Sub. 8 Add M.	S.	Degrees
0	0	0	2	22	4	12	30
1	0	5	2	26	4	15	29
2	0	10	2	30	4	18	28
3	0	15	2	34	4	21	27
4	0	20	2	38	4	24	26
5	0	25	2	42	4	27	25
6	0	30	2	46	4	30	24
7	0	35	2	50	4	32	23
8	0	40	2	54	4	34	22
9	0	45	2	58	4	36	21
10	0	50	3	2	4	38	20
11	0	55	3	6	4	40	19
12	1	0	3	10	4	42	18
13	1	5	3	14	4	44	17
14	1	10	3	18	4	46	16
15	1	15	3	22	4	48	15
16	1	20	3	26	4	50	14
17	1	25	3	30	4	51	13
18	1	30	3	34	4	52	12
19	1	35	3	38	4	53	11
20	1	40	3	42	4	54	10
21	1	45	3	45	4	55	9
22	1	49	3	48	4	56	8
23	1	52	3	51	4	57	7
24	1	56	3	54	4	57	6
25	2	0	3	57	4	57	5
26	2	4	4	0	4	58	4
27	2	9	4	3	4	58	3
28	2	13	4	6	4	58	2
29	2	18	4	9	4	58	1
30	2	22	4	12	4	58	0
Degrees	Signs 5 Sub. 11 Add		Signs 4 Sub. 10 Add		Signs 3 Sub. 9 Add		Degrees

TABLE XI. *The fourth Equation of the mean to the true Syzygy.*

Argument. Sun's mean Distance from the Node

Add

Degrees	0, 6 Sig. M.	S.	1, 7 Sig. M.	S.	2, 8 Sig. M.	S.	Degrees
0	0	0	1	22	1	22	30
1	0	4	1	23	1	21	29
2	0	7	1	24	1	20	28
3	0	10	1	25	1	18	27
4	0	13	1	26	1	16	26
5	0	16	1	27	1	14	25
6	0	20	1	28	1	12	24
7	0	23	1	29	1	10	23
8	0	26	1	30	1	8	22
9	0	29	1	31	1	6	21
10	0	32	1	32	1	3	20
11	0	35	1	33	1	0	19
12	0	38	1	33	0	57	18
13	0	41	1	34	0	54	17
14	0	44	1	34	0	51	16
15	0	47	1	34	0	49	15
16	0	50	1	34	0	45	14
17	0	52	1	34	0	41	13
18	0	54	1	34	0	37	12
19	0	57	1	33	0	34	11
20	1	0	1	33	0	31	10
21	1	2	1	32	0	28	9
22	1	5	1	31	0	25	8
23	1	8	1	30	0	22	7
24	1	10	1	29	0	19	6
25	1	12	1	28	0	16	5
26	1	14	1	27	0	13	4
27	1	16	1	26	0	10	3
28	1	18	1	25	0	6	2
29	1	20	1	24	0	3	1
30	1	22	1	22	0	0	0
Deg.	5, 11 Sig.		4, 10 Sig.		3, 9 Sig.		Deg.

Subtract

TABLE XII. *The Sun's mean Longitude, Motion, and Anomaly: Old Stile.*

Years beginning	Sun's mean Longitude. s	°	′	″	Sun's mean Anomaly. s	°	′
1	9	7	53	10	6	28	48
201	9	9	23	50	6	26	57
301	9	10	9	10	6	26	1
401	9	10	54	30	6	25	5
501	9	11	39	50	6	24	9
1001	9	15	26	30	6	19	32
1101	9	16	11	50	6	18	36
1201	9	16	57	10	6	17	40
1301	9	17	42	30	6	16	44
1401	9	18	27	50	6	15	49
1501	9	19	13	10	6	14	53
1601	9	19	58	30	6	13	57
1701	9	20	43	50	6	13	1
1801	9	21	29	10	6	12	6

Years compleat	Sun's mean Motion. s	°	′	″	Sun's mean Anomaly. s	°	′
1	11	29	45	40	11	29	45
2	11	29	31	20	11	29	29
3	11	29	17	0	11	29	14
4	0	0	1	49	11	29	58
5	11	29	47	29	11	29	42
6	11	29	33	9	11	29	27
7	11	29	18	49	11	29	11
8	0	0	3	38	11	29	55
9	11	29	49	18	11	29	40
10	11	29	34	58	11	29	24
11	11	29	20	38	11	29	9
12	0	0	5	26	11	29	53
13	11	29	51	7	11	29	37
14	11	29	36	47	11	29	22
15	11	29	22	27	11	29	7
16	0	0	7	15	11	29	50
17	11	29	52	55	11	29	35
18	11	29	38	35	11	29	20
19	11	29	24	16	11	29	4
20	0	0	9	4	11	29	48
40	0	0	18	8	11	29	37
60	0	0	27	12	11	29	26
80	0	0	36	16	11	29	15
100	0	0	45	20	11	29	4
200	0	1	30	40	11	28	8
300	0	2	16	0	11	27	12
400	0	3	1	20	11	26	16
500	0	3	46	40	11	25	21
600	0	4	32	0	11	24	25
700	0	5	17	20	11	23	29
800	0	6	2	40	11	22	33
900	0	6	48	0	11	21	37
1000	0	7	33	20	11	20	41
2000	0	15	6	40	11	11	22
3000	0	22	40	0	11	2	3
4000	1	0	13	20	10	22	44
5000	1	7	46	40	10	13	25
6000	1	15	20	0	10	4	6

Months	Sun's mean Motion. s	°	′	″	Sun's mean Anomaly. s	°	′
Jan.	0	0	0	0	0	0	0
Feb.	1	0	33	18	1	0	33
Mar.	1	28	9	11	1	28	9
Apr.	2	28	42	30	2	28	42
May	3	28	16	40	3	28	17
June	4	28	49	58	4	28	50
July	5	28	24	8	5	28	24
Aug.	6	28	57	26	6	28	57
Sept.	7	29	30	44	7	29	30
Oct.	8	29	4	54	8	29	4
Nov.	9	29	38	12	9	29	37
Dec.	10	29	12	22	10	29	11

TABLE XII. *concluded.*

Days.	Sun's mean Motion and Anomaly.				H M S	Sun's mean Motion and Anomaly.			Sun's mean Dist. from Node.			H M S	Sun's mean Motion and Anomaly.			Sun's mean Dist. from Node.		
	s	°	′	″		° ′ ″	′ ″ ‴	″ ‴ ⁗	° ′ ″	′ ″ ‴	″ ‴ ⁗		° ′ ″	′ ″ ‴	″ ‴ ⁗	° ′ ″	′ ″ ‴	″ ‴ ⁗
1	0	0	59	8														
2	0	1	58	17	1	0	2	28	0	2	36	31	1	16	23	1	20	30
3	0	2	57	25	2	0	4	56	0	5	12	32	1	18	51	1	23	6
4	0	3	56	33	3	0	7	24	0	7	48	33	1	21	19	1	25	42
5	0	4	55	42	4	0	9	51	0	10	23	34	1	23	47	1	28	18
6	0	5	54	50	5	0	12	19	0	12	59	35	1	26	15	1	30	54
7	0	6	53	58	6	0	14	47	0	15	35	36	1	28	42	1	33	29
8	0	7	53	7	7	0	17	15	0	18	11	37	1	31	10	1	36	5
9	0	8	52	15	8	0	19	43	0	20	47	38	1	33	38	1	38	40
10	0	9	51	23	9	0	22	11	0	23	23	39	1	36	6	1	41	16
11	0	10	50	32	10	0	24	38	0	25	58	40	1	38	34	1	43	52
12	0	11	49	40	11	0	27	6	0	28	34	41	1	41	2	1	46	28
13	0	12	48	48	12	0	29	34	0	31	10	42	1	43	30	1	49	4
14	0	13	47	57	13	0	32	2	0	33	45	43	1	45	57	1	51	39
15	0	14	47	5	14	0	34	30	0	36	21	44	1	48	25	1	54	15
16	0	15	46	13	15	0	36	58	0	38	57	45	1	50	53	1	55	51
17	0	16	45	22	16	0	39	26	0	41	33	46	1	53	21	1	59	27
18	0	17	44	30	17	0	41	53	0	43	8	47	1	55	49	2	2	3
19	0	18	43	38	18	0	44	21	0	46	4	48	1	58	17	2	4	39
20	0	19	42	47	19	0	46	49	0	49	20	49	2	0	44	2	7	13
21	0	20	41	55	20	0	49	17	0	51	5	50	2	3	12	2	9	50
22	0	21	41	3	21	0	51	45	0	54	32	51	2	5	40	2	12	25
23	0	22	40	12	22	0	54	13	0	57	8	52	2	8	8	2	15	2
24	0	23	39	20	23	0	56	40	0	59	43	53	2	10	36	2	17	38
25	0	24	38	28	24	0	59	8	1	2	19	54	2	13	4	2	20	14
26	0	25	37	37	25	1	1	36	1	4	55	55	2	15	32	2	22	50
27	0	26	36	45	26	1	4	4	1	7	31	56	2	17	59	2	25	26
28	0	27	35	53	27	1	6	32	1	10	7	57	2	20	27	2	28	2
29	0	28	35	2	28	1	9	0	1	12	43	58	2	22	5	2	30	35
30	0	29	34	10	29	1	11	2	1	15	19	59	2	25	23	2	33	11
31	1	0	33	18	30	1	13	55	1	17	55	60	2	27	51	2	35	50

In Leap-years, after *February*, add one day, and one day's motion.

TABLE XIII. *Equation of the Sun's center, or the difference between his mean and true Place.*

Argument. Sun's mean Anomaly.

Subtract

Degrees	0 Signs	1 Sign	2 Signs	3 Signs	4 Signs	5 Signs	Degrees
	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″	
0	0 0 0	0 56 47	1 39 6	1 55 37	1 41 12	0 58 33	30
1	0 1 59	0 58 30	1 40 7	1 55 39	1 40 12	0 57 7	29
2	0 3 57	1 0 12	1 41 6	1 55 38	1 39 10	0 55 19	28
3	0 5 56	1 1 53	1 42 3	1 55 36	1 38 6	0 53 30	27
4	0 7 54	1 3 33	1 42 59	1 55 31	1 37 0	0 51 40	26
5	0 9 52	1 5 12	1 43 52	1 55 24	1 35 52	0 49 49	25
6	0 11 50	1 6 50	1 44 44	1 55 15	1 34 43	0 47 57	24
7	0 13 48	1 8 27	1 45 34	1 55 3	1 33 32	0 46 5	23
8	0 15 46	1 10 2	1 46 22	1 54 50	1 32 19	0 44 11	22
9	0 17 43	1 11 36	1 47 8	1 54 35	1 31 4	0 42 16	21
10	0 19 40	1 13 9	1 47 53	1 54 17	1 29 47	0 40 21	20
11	0 21 37	1 14 41	1 48 35	1 53 57	1 28 29	0 38 25	19
12	0 23 33	1 16 11	1 49 15	1 53 36	1 27 9	0 36 28	18
13	0 25 29	1 17 40	1 49 54	1 53 12	1 25 48	0 34 30	17
14	0 27 25	1 19 8	1 50 30	1 52 46	1 24 25	0 32 32	16
15	0 29 20	1 20 34	1 51 5	1 52 18	1 23 0	0 30 33	15
16	0 31 15	1 21 59	1 51 37	1 51 48	1 21 34	0 28 33	14
17	0 33 9	1 23 22	1 52 8	1 51 15	1 20 6	0 26 33	13
18	0 35 2	1 24 44	1 52 36	1 50 41	1 18 36	0 24 33	12
19	0 36 55	1 26 5	1 53 3	1 50 5	1 17 5	0 22 32	11
20	0 38 47	1 27 24	1 53 27	1 49 26	1 15 33	0 20 30	10
21	0 40 39	1 28 41	1 53 50	1 48 46	1 13 59	0 18 28	9
22	0 42 30	1 29 57	1 54 10	1 48 3	1 12 24	0 16 26	8
23	0 44 20	1 31 11	1 54 28	1 47 19	1 10 47	0 14 24	7
24	0 46 9	1 32 25	1 54 44	1 46 32	1 9 9	0 12 21	6
25	0 47 57	1 33 35	1 54 58	1 45 44	1 7 29	0 10 18	5
26	0 49 45	1 34 45	1 55 10	1 44 53	1 5 49	0 8 14	4
27	0 51 32	1 35 53	1 55 20	1 44 1	1 4 7	0 6 11	3
28	0 53 18	1 36 59	1 55 28	1 43 7	1 2 24	0 4 7	2
29	0 55 3	1 38 3	1 55 34	1 42 10	1 0 39	0 2 4	1
30	0 56 47	1 39 6	1 55 37	1 41 12	0 58 53	0 0 0	0
Deg.	11 Signs	10 Signs	9 Signs	8 Signs	7 Signs	6 Signs	Deg.

Add

TABLE XIV. *The Sun's Declination.*

Argument. Sun's true Place.

Degrees	Signs. 0 N. 6 S. °	′	Signs. 1 N. 7 S. °	′	Signs. 2 N. 8 S. °	′	Degrees
0	0	0	11	30	20	11	30
1	0	24	11	51	20	24	29
2	0	48	12	11	20	36	28
3	1	12	12	32	20	48	27
4	1	36	12	53	20	59	26
5	1	59	13	13	21	10	25
6	2	23	13	33	21	21	24
7	2	47	13	53	21	31	23
8	3	11	14	12	21	41	22
9	3	34	14	31	21	50	21
10	3	58	14	50	21	59	20
11	4	22	15	9	22	8	19
12	4	45	15	28	22	16	18
13	5	9	15	46	22	24	17
14	5	32	16	4	22	31	16
15	5	55	16	22	22	38	15
16	6	18	16	39	22	45	14
17	6	41	16	57	22	51	13
18	7	4	17	14	22	56	12
19	7	27	17	30	23	2	11
20	7	50	17	46	23	6	10
21	8	13	18	2	23	11	9
22	8	35	18	18	23	14	8
23	9	57	18	33	23	18	7
24	9	20	18	48	23	21	6
25	9	42	19	3	23	23	5
26	10	4	19	17	23	25	4
27	10	25	19	31	23	27	3
28	10	47	19	45	23	28	2
29	11	8	19	58	23	29	1
30	11	30	20	11	23	29	0
Degrees	Signs. 11 S. 5 N.		Signs. 10 S. 4 N.		Signs. 9 S. 3 N.		Degrees

TABLE XV. *Equation of the Sun's mean Distance from the Node.*

Argument. Sun's mean Anomaly.

Subtract

Degrees	0 Signs. °	′	1 Sign °	′	2 Signs. °	′	3 Signs. °	′	4 Signs. °	′	5 Signs. °	′	Degrees
0	0	0	1	2	1	47	2	5	1	50	1	4	30
1	0	2	1	4	1	48	2	5	1	48	1	2	29
2	0	4	1	6	1	49	2	5	1	47	1	0	28
3	0	6	1	8	1	50	2	5	1	46	0	58	27
4	0	9	1	10	1	51	2	5	1	45	0	56	26
5	0	11	1	12	1	52	2	5	1	44	0	54	25
6	0	13	1	14	1	53	2	5	1	43	0	52	24
7	0	15	1	16	1	54	2	4	1	41	0	50	23
8	0	17	1	17	1	55	2	4	1	40	0	48	22
9	0	19	1	18	1	56	2	4	1	39	0	46	21
10	0	21	1	19	1	57	2	4	1	37	0	44	20
11	0	23	1	21	1	58	2	3	1	36	0	42	19
12	0	25	1	22	1	58	2	3	1	34	0	40	18
13	0	28	1	24	1	59	2	3	1	33	0	37	17
14	0	30	1	26	2	0	2	2	1	31	0	35	16
15	0	32	1	27	2	0	2	2	1	30	0	33	15
16	0	34	1	28	2	1	2	1	1	28	0	31	14
17	0	36	1	30	2	1	2	1	1	27	0	29	13
18	0	38	1	31	2	2	2	0	1	25	0	27	12
19	0	40	1	34	2	2	2	0	1	24	0	24	11
20	0	42	1	35	2	3	1	59	1	23	0	22	10
21	0	44	1	36	2	3	1	59	1	21	0	20	9
22	0	46	1	37	2	4	1	58	1	19	0	18	8
23	0	48	1	39	2	4	1	57	1	17	0	16	7
24	0	50	1	40	2	4	1	56	1	15	0	13	6
25	0	52	1	41	2	4	1	55	1	13	0	11	5
26	0	54	1	43	2	5	1	54	1	11	0	9	4
27	0	56	1	44	2	5	1	53	1	9	0	7	3
28	0	58	1	45	2	5	1	52	1	8	0	5	2
29	1	0	1	46	2	5	1	51	1	6	0	3	1
30	1	2	1	47	2	5	1	50	1	4	0	0	0
Deg.	11 Signs.		10 Signs.		9 Signs.		8 Signs.		7 Signs.		6 Signs.		Deg.

Add

TABLE XVI. *The Moon's Latitude in Eclipses.*

Argument Moon's equated Distance from the Node.

0 Signs. *North Ascending.*

6 Signs. *South Descending.*

°	°	'	''	°
0	0	0	0	30
1	0	5	15	29
2	0	10	30	28
3	0	15	45	27
4	0	20	59	26
5	0	26	13	25
6	0	31	26	24
7	0	36	39	23
8	0	41	51	22
9	0	47	2	21
10	0	52	13	20
11	0	57	23	19
12	1	2	31	18
13	1	7	38	17
14	1	12	44	16
15	1	17	49	15
16	1	22	52	14
17	1	27	53	13
18	1	32	52	12
19	1	37	49	11

5 Signs. *North Descending*

11 Signs. *South Ascending.*

This Table shews the Moon's Latitude a little beyond the utmost Limits of Eclipses.

TABLE XVII. *The Moon's horizontal Parallax, with the Semidiameters and true Horary Motions of the Sun and Moon, to every sixth degree of their mean Anomalies; the quantities for the intermediate degrees being easily proportioned by sight.*

Anomaly of Sun and Moon.		Moon's horizont. Parallax.		Sun's Semidiameter		Moon's Semidiameter.		Moon's Horary Motion.		Sun's Horary Motion.		of Sun and Moon.	
s	°	'	''	'	''	'	''	'	''	'	''	s	
0	0	54	29	15	50	14	54	30	10	2	23	12	
	6	54	31	15	50	14	55	30	12	2	23		2
	12	54	34	15	50	14	56	30	15	2	23		1
	18	54	40	15	51	14	57	30	19	2	23		1
	24	54	47	15	51	14	58	30	26	2	23		
1	0	54	56	15	52	14	59	30	34	2	24	11	
	6	55	6	15	53	15	1	30	44	2	24		2
	12	55	17	15	54	15	4	30	55	2	24		1
	18	55	29	15	55	15	8	31	9	2	24		1
	24	55	42	15	56	15	12	31	23	2	25		
2	0	55	56	15	58	15	17	31	40	2	25	10	
	6	56	12	15	59	15	22	31	56	2	26		2
	12	56	29	16	1	15	26	32	17	2	27		1
	18	56	48	16	2	15	30	32	39	2	27		1
	24	57	8	16	4	15	36	33	11	2	28		
3	0	57	30	16	6	15	41	33	23	2	28	9	
	6	57	52	16	8	15	46	33	47	2	29		2
	12	58	12	16	10	15	52	34	11	2	29		1
	18	58	31	16	11	15	58	34	34	2	29		1
	24	58	49	16	13	16	3	34	58	2	30		
4	0	59	6	16	14	16	9	35	22	2	30	8	
	6	59	21	16	15	16	14	35	45	2	31		2
	12	59	35	16	17	16	19	36	0	2	31		1
	18	59	48	16	19	16	24	36	20	2	32		1
	24	60	0	16	20	16	28	36	40	2	32		
5	0	60	11	16	21	16	31	37	0		32	7	
	6	60	21	16	21	16	34	37	10	2	33		2
	12	60	30	16	22	16	37	37	19	2	33		1
	18	60	38	16	2	16	38	37	28	2	33		1
	24	60	45	16	23	16	39	37	3[illegible]	2	33		
6	0	60	45	16	23	16	39	37	40	2	33	6	

To calculate the true Time of New or full Moon.

Precept I. If the required time be within the limits of the 18th century, write out the mean time of New Moon in *March*, for the propofed year, from Table I. in the Old Stile, or from Table II. in the New; together with the mean Anomalies of the Sun and Moon, and the Sun's mean Diftance from the Moon's afcending Node.—If you want the time of full Moon in *March*, add the half Lunation at the foot of Table III, with it's Anomalies, &c. to the former numbers, if the New Moon falls before the 15th of *March*; but if it falls after, fubtract the half Lunation, with the Anomalies, &c. belonging to it, from the former numbers, and write down the refpective fums or remainders.

II. In thefe additions or fubtractions, obferve, that 60 feconds make a minute, 60 minutes make a degree, 30 degrees make a fign, and 12 figns make a circle.—When you exceed 12 figns in addition, reject 12, and fet down the remainder.—When the number of figns to be fubtracted is greater than the number you fubtract from, add 12 figns to the leffer number, and then you will have a remainder to fet down.—In the Tables, figns are marked thus ^{s}, degrees thus $^\circ$, minutes thus $'$, and feconds thus $''$.

III. When the required New or Full Moon is in any given month after *March*, write out as many Lunations, with their Anomalies, and the Sun's diftance from the Node, from Table III, as the given month is after *March*; fetting them in order below the numbers taken out for *March*.

IV. Add all thefe together, and they will give the mean time of the required New or Full Moon, with the mean Anomalies and Sun's mean diftance from the afcending Node, which are the Arguments for finding the proper Equations.

V. With the number of days added together, enter Table IV. under the given Month; and againſt that number you have the day of mean New or Full Moon in the left-hand column, which ſet before the hours, minutes, and ſeconds, already found.

But (as it will ſometimes happen) if the ſaid number of days falls ſhort of any in the column under the given month, add one Lunation and it's Anomalies, &c. (from Table III.) to the foreſaid ſums, and then you will have a new ſum of days wherewith to enter Table IV. under the given month, where you are ſure to find it the ſecond time, if the firſt falls ſhort.

VI. With the ſigns and degrees of the Sun's Anomaly, enter Table VII. and therewith take out the annual or firſt Equation for reducing the mean Syzygy to the true; taking care to make proportions in the Table for the odd minutes and ſeconds of Anomaly, as the Table gives the Equation only to whole degrees.

Obſerve, in this and every other caſe of finding Equations, that if the ſigns are at the head of the Table, their degrees are at the left hand, and are reckoned downwards; but if the ſigns are at the foot of the Table, their degrees are at the right hand, and are counted upward; the Equation being in the body of the Table, under or over the ſigns, in a collateral line with the degrees.—The titles *Add* or *Subtract* at the head or foot of the Tables where the ſigns are found, ſhew whether the Equation is to be added to the mean time of New or Full Moon, or to be ſubtracted from it. In this Table, the Equation is to be ſubtracted, if the ſigns of the Sun's Anomaly are found at the head of the Table; but it is to be added, if the ſigns are at the foot.

VII. With the ſigns and degrees of the Sun's mean Anomaly, enter Table VIII. and take out the Equation of the Moon's mean Anomaly; ſub-
tract

tract this Equation from her mean Anomaly, if the signs of the Sun's Anomaly be at the head of the Table, but add it if they are at the foot; the result will be the Moon's equated Anomaly, with which enter Table IX, and take out the second Equation for reducing the mean to the true time of New or Full Moon; adding this Equation, if the signs of the Moon's Anomaly are at the head of the Table, but subtracting it if they are at the foot, and the result will give you the mean time of the required New or Full Moon twice equated, which will be sufficiently near for common almanacks.—But when you want to calculate an Eclipse, the following Equations must be used: thus,

VIII. Subtract the Moon's equated Anomaly from the Sun's mean Anomaly, and with the remainder in signs and degrees, enter Table X, and take out the third Equation, applying it to the former equated time, as the titles, *Add* or *Subtract*, do direct.

IX. With the Sun's mean distance from the ascending Node enter Table XI, and take out the Equation answering to that argument, adding it to, or subtracting it from the former equated time, as the titles direct, and the result will give the time of New or Full Moon, agreeing with well-regulated clocks or watches, very near the truth. But, to make it agree with the solar, or apparent time, apply the Equation of natural days, for in the Tables (from page 161 to page 173) as it is Leap-year, or the first, second, or third after.

The method of calculating the time of any New or Full Moon without the limits of the 18th century, will be shewn further on. And a few Examples compared with the Precepts, will make the whole work plain.

N. B. The Tables begin the day at noon, and reckon forward from thence to the noon following.—Thus, *March* the 31st, at 22 h. 30 min. 25 sec. of tabular time, is *April* 1st (in common reckoning) at 30 min. 25 sec. after 10 o'clock in the morning.

EXAMPLE I.

Required the true time of New Moon in April 1764, *New Stile?*

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fr. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1764,	2 8 55 36	8 2 20 0	10 13 35 21	11 4 54 48
Add 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
Mean New Moon,	31 21 39 39	9 1 26 19	11 9 24 21	0 5 35 2
First Equation,	+ 4 10 40	11 10 59 18	+ 1 34 57	
Time once equated,	32 1 50 19	9 20 27 1	11 10 59 18	Sun fr. Node, and Arg. 4th. equation.
Second Equation,	— 3 24 49	Arg. 3d equat.	Arg. 2d equat	
Time twice equat.	31 22 25 30			
Third Equation,	+ 4 37			
Time thrice equat.	31 22 30 7			
Fourth Equation,	+ 18			
True New Moon,	31 22 30 25			
Equation of days,	— 3 48			
Apparent time,	31 22 26 37			

So the true time is 22 h. 30 min. 25 sec. after the noon of the 31st *March*; that is, *April* 1st, at 30 min. 25 sec. after X in the morning. But the apparent time is 26 min. 37 sec. after X in the morning.

EXAMPLE

EXAMPLE II.

Qu. *The true time of Full Moon in* May 1762, *New Stile?*

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom. s ° ′ ″	Moon's Anom. s ° ′ ″	Sun fr. Node. s ° ′ ″
March 1762,	24 15 18 24	8 23 48 16	1 23 59 11	10 18 49 14
Add 2 Lunations,	59 1 28 0	1 28 12 59	1 21 38 1	2 1 20 28
New Moon, *May*,	22 16 45 30	10 22 0 55	3 15 37 12	0 20 9 42
Subt. ½ Lunation,	14 18 22 2	0 14 33 10	6 12 54 30	0 15 20 7
Full Moon, *May*,	7 22 24 28	10 7 27 45	9 2 42 42	0 4 49 35
First Equation,	+ 3 16 36	9 3 57 18	+ 1 14 36	Sun fr. Node, and Arg. 4th equation.
Time once equat.	8 1 41 4	1 3 30 27	9 3 57 18	
Second Equation,	− 9 47 53	Arg. 3d equat.	Arg. 2d equat	
Time twice equat.	7 15 53 11			
Third Equation,	− 2 36			
Time thrice equat.	7 15 50 35			
Fourth Equation,	+ 15			
The Full Moon,	7 15 50 50			

Anſ. *May* 7th at 15 h. 50 min. 50 ſec. paſt noon, viz. *May* 8th at III h. 50 min. 50 ſec. in the morning.

To calculate the time of New and Full Moon in a given year and month of any particular century, between the Chriſtian Æra and the 18th century.

Precept I. Find a year of the ſame number in the 18th century with that of the year in the century propoſed, and take out the mean Time of New Moon in *March*, Old Stile, for that year, with the mean Anomalies and Sun's mean Diſtance from the Node at that time, as already taught.

II. Take as many compleat centuries of years from Table VI. as, when ſubtracted from the abovesaid year in the 18th century, will anſwer to the given year; and take

 out

out the firſt mean new Moon and it's Anomalies, &c. belonging to the ſaid centuries, and ſet them below thoſe taken out for *March* in the 18th century.

III. Subtract the Numbers belonging to theſe centuries, from thoſe of the 18th century, and the remainders will be the mean Time and Anomalies, &c. of New Moon in *March*, in the given year of the century propoſed.—Then, work in all reſpects for the true time of New or Full Moon, as ſhewn in the above Precepts and Examples.

IV. If the days annexed to theſe centuries exceed the number of days from the beginning of *March* taken out in the 18th century, add a Lunation and it's Anomalies, &c. from Table III. to the Time and Anomalies of New Moon in *March*, and then proceed in all reſpects as above.—This circumſtance happens in Example V.

EXAMPLE III.

Required the true time of Full Moon in April, *Old Stile, A. D.* 30?

From 1730 ſubtract 1700 (or 17 centuries) and there remains 30.

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom. s ° ′ ″	Moon's Anom. s ° ′ ″	Sun fr. Node. s ° ′ ″
March 1730,	7 12 34 16	8 18 4 31	9 0 32 17	1 23 17 16
Add ½ Lunation,	14 18 22 2	0 14 33 10	6 12 54 30	0 15 20 7
Full Moon,	22 6 56 18	9 2 37 41	3 13 26 47	2 8 37 23
1700 years ſubtr.	14 17 36 42	11 28 46 0	10 29 36 0	4 29 23 0
Full ☽ *Mar. A D.* 30,	7 13 19 36	9 3 51 41	4 13 50 47	9 9 14 23
Add 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
Full Moon, *April*,	6 2 3 39	10 2 58 0	5 9 39 47	10 9 54 37
Firſt Equation,	+ 3 28 4	5 10 58 40	+ 1 18 53	Sun fr. Node,
Time once equat.	6 5 31 43	4 21 59 20	5 10 58 40	and Arg. fourth
Second Equation,	+ 2 57 48	Arg. 3d equat.	Arg. 2d equat.	equation.
Time twice equat.	6 8 29 31			
Third Equation,	— 2 54			
Time thrice equat.	6 8 26 37			
Fourth Equation,	— 1 33			
Tr. Full Moon, *Apr.*	6 8 25 4			

Hence it appears, that the true time of Full Moon in *April, A. D.* 30, Old Stile, was on the 6th day, at 25 m. 4 ſ. paſt VIII in the evening.

To calculate the true time of New or Full Moon in any given year and month before the Christian Æra.

Precept I. Find a year in the 18th century, which being added to the given number of years before Chrift diminifhed by one, fhall make a number of compleat centuries.

II. Find this number of centuries in Table VI. and fubtract the Time and Anomalies belonging to it from thofe of the mean New Moon in *March*, the above-found year of the 18th century; and the remainder will denote the Time and Anomalies, &c. of mean New Moon in *March*, the given year before Chrift.—Then, for the true time thereof in any month of that year, proceed as above taught.

EXAMPLE IV.

Required the true time of New Moon in May, *Old Stile, the year before Chrift* 585?

The years 584 added to 1716, make 2300, or 23 centuries.

By the Precepts.	New Moon.	Sun's Anom.	Moon's Anom.	Sun fr. Node.
	D. H. M. S.	s ° ′ ″	s ° ′ ″	s ° ′ ″
March 1716,	11 17 33 29	8 22 50 39	4 4 14 2	4 27 17 5
2300 years fubt.	11 5 57 53	11 19 47 0	1 5 59 0	7 25 27 0
Mar. bef. Ch. 585,	0 11 35 36	9 3 3 39	2 28 15 2	9 1 50 5
Add 3 Lunations,	88 14 12 9	2 27 18 58	2 17 27 1	3 2 0 42
May bef. Ch. 585,	28 1 47 45	0 0 22 37	5 15 42 3	0 3 50 47
Firft Equation,	— 1 37	5 15 41 17	— 46	Sun fr. Node, and Arg. fourth equation.
Time once equat.	28 1 46 8	6 14 41 20.	5 15 41 17	
Second Equation,	+ 2 15 1	Arg. 3d equat.	Arg. 2d equat.	
Time twice equat.	28 4 1 9			
Third Equation,	+ 1 9			
Time thrice equat.	28 4 2 18			
Fourth Equation,	+ 12			
True New Moon,	28 4 2 30			

So the true time was *May* 28th, at 2 minutes 30 feconds paft IV in the afternoon.

These Tables are calculated for the meridian of *London*; but they will serve for any other place, by subtracting four minutes from the tabular time, for every degree that the meridian of the given place is westward of *London*, or adding four minutes for every degree that the meridian of the given place is eastward: as in

EXAMPLE V.

Required the true time of Full Moon at Alexandria *in* Egypt *in* September, *Old Stile, the year before Christ* 201?

The years 200 add to 1800, make 2000, or 20 centuries.

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom. s ° ′ ″	Moon's Anom. s ° ′ ″	Sun fr. Node. s ° ′ ″
March 1800,	13 0 22 17	8 23 19 55	10 7 52 36	11 3 58 24
Add 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 14
From the sum,	42 13 6 20	9 22 26 14	11 3 41 36	0 4 38 38
Subtr. 2000 years,	27 18 9 19	0 8 50 0	0 15 42 0	6 27 45 0
N.M. bef. Chr. 201,	14 18 57 1	9 13 36 14	10 17 59 36	5 6 53 38
Add { 6 Lunations,	177 4 24 18	5 24 37 56	5 4 54 3	6 4 1 24
Add { half Lunat.	14 18 22 2	0 14 33 10	6 12 51 30	0 15 20 7
Full Moon *Sept.*	22 17 43 21	3 22 47 20	10 5 48 9	11 26 15 9
First Equation,	— 3 52 6	10 4 19 55	— 1 28 14	Sun fr. Node,
Time once equat.	22 13 51 15	5 18 27 25	10 4 19 55	and Arg. 4th
Second Equation,	— 8 25 4	Arg. 3d equat	Arg. 2d equat	equation.
Time twice equat.	22 5 26 11			
Third Equation,	— 58			
Time thrice equat.	22 5 25 13			
Fourth Equation,	— 12			
Tr. time at *London*,	22 5 25 1			
Add for *Alexandria*,	2 1 27			
True time there,	22 7 26 28			

Thus it appears, that the true time of Full Moon at *Alexandria*, in *September*, Old Stile, the year before Christ 201, was the 22d day, at 26 m. 28 s. after VII in the evening.

EXAMPLE

EXAMPLE VI.

Required the true time of Full Moon at Babylon *in* October, *Old Stile, the* 4008 *year before the first year of Christ, or* 4007 *before the year of his birth?*

The years 4007 added to 1793, make 5800, or 58 centuries.

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom. s ° ′ ″	Moon's Anom. s ° ′ ″	Sun fr. Node. s ° ′ ″
March 1793,	30 9 13 55	9 10 16 11	8 7 37 53	7 6 18 26
Subtr. 5800 years,	15 12 38 7	10 21 35 0	6 24 43 0	9 13 1 0
N.M.bef.Chr.4007,	14 20 35 48	10 18 41 11	1 12 54 58	9 23 17 26
Add { 7 Lunations,	206 17 8 21	6 23 44 15	6 0 43 3	7 4 41 38
{ half Lunat.	14 18 22 2	0 14 33 10	6 12 54 30	0 15 20 7
Full Moon, *October*,	22 8 6 11	5 26 58 36	1 26 32 31	5 13 19 11
First Equation,	— 13 26	1 26 27 26	— 5 5	Sun fr Node,
Time once equat.	22 7 52 45	4 0 3 10	1 26 27 26	and Arg. 4th
Second Equation,	+ 8 29 21	Arg. 3d equat.	Arg. 2d equat.	equation.
Time twice equat.	22 16 22 6			
Third Equation,	— 4 10			
Time thrice equat.	22 16 17 56			
Fourth Equation,	— 51			
Full Moon at *London*,	22 16 17 5			
Add for *Babylon*,	2 25 41			
True time there,	22 18 42 46			

So that, on the meridian of *London*, the true time was *October* 23d, at 17 min. 5 sec. past IV in the morning; but at *Babylon*, the true time was *October* 23d, at 42 min. 46 sec. past VI in the morning.—This is supposed by some to have been the year of the Creation.

To calculate the true time of New or Full Moon in any given year and Month after the 18th century.

Precept I. Find a year of the same number in the 18th century with that of the year proposed, and take out the mean Time and Anomalies, &c. of New Moon in *March*, Old Stile, for that year, in Table I.

II. Take so many years from Table VI. as when added to the above-mentioned year in the 18th century, will answer to the given year in which the New or Full Moon is required: and take out the first New Moon, with its Anomalies for these compleat centuries.

 III. Add

III. Add all these together, and then work in all respects as above shewn, only remember to subtract a Lunation and its Anomalies, when the abovesaid addition carries the New Moon beyond the 31st of *March*; as in the following example.

EXAMPLE VII.

Required the true time of New Moon in July, *Old Stile*, A. D. 2180?

Four centuries (or 400 years) added to *A. D.* 1780, make 2180.

By the Precepts.	New Moon. D. H. M. S.	Sun's Anom s ° ′ ″	Moon's Anom. s ° ′ ″	Sun fr. Node s ° ′ ″
March 1780,	23 23 1 44	9 4 18 13	1 21 7 47	10 18 21 1
Add 400 years,	17 8 43 29	0 13 24 0	10 1 28 0	6 17 49 0
From the sum	41 7 45 13	9 17 42 13	11 22 35 47	5 6 10 1
Subtr. 1 Lunation,	29 12 44 3	0 29 6 19	0 25 49 0	1 0 40 1
New ☽ *March* 2180,	11 19 1 10	8 18 35 54	10 26 46 47	4 5 29 47
Add 4 Lunations,	118 2 56 12	3 26 25 17	3 13 16 2	4 2 40 56
N. ☽ *July* 2180,	7 21 57 22	0 15 1 11	2 10 2 49	8 8 10 43
First equation,	— 1 3 39	3 9 38 37	— 24 12	Sun fr. Node,
Time once equat.	7 20 53 43	10 5 22 34	2 9 38 37	and Arg. 4th
Second equation,	+ 9 24 8	Arg 3d equat	Arg. 2d equat.	equation.
Time twice equat.	8 6 17 51			
Third equation,	+ 3 56			
Time thrice equat.	8 6 21 47			
Fourth equation,	+ 1 8			
True time, *July*,	8 6 22 55			

True time, *July* 8, at 22 minutes 55 seconds past VI in the evening.

In keeping by the Old Style, we are always sure to be right, by adding or subtracting whole hundreds of years to or from any given year in the 18th century. But in the New Stile we may be very apt to make mistakes, on account of the Leap-year's not coming in regularly every fourth year:—And therefore, when we go without the limits

limits of the 18th century, we had beſt keep to the Old Stile, and at the end of the calculation reduce the time to the New. Thus, in the 22d century, there will be 14 days difference between the Stiles; and therefore, the true time of New Moon in this laſt Example being reduced to the New Stile, will be the 22d of *July*, at 22 minutes 55 ſeconds paſt VI in the evening.

To calculate the true place of the Sun for any given moment of time.

Precept I. In Table XII. find the next leſſer year in number to that in which the Sun's place is ſought, and write out his mean Longitude and Anomaly anſwering thereto: to which add his mean Motion and Anomaly for the compleat reſidue of years, months, days, hours, minutes and ſeconds, down to the given time, and this will be the Sun's mean Place and Anomaly at that time, in the Old Stile, provided the ſaid time be in any year after the Chriſtian æra. *See the firſt following Example.*

II. Enter Table XIII with the Sun's mean anomaly, and making proportions for the odd minutes and ſeconds thereof, take out the Equation of the Sun's center; which, being applied to his mean Place as the title *Add* or *Subtract* directs, will give his true Place or Longitude from the Vernal Equinox, at the time for which it was required.

III. To calculate the Sun's place for any time in a given year before the Chriſtian æra, take out his mean Longitude and Anomaly for the firſt year thereof, and from theſe numbers, ſubtract the mean Motions and Anomalies for the compleat hundreds or thouſands next above the given year; and, to the remainders, add thoſe for the reſidue of years, months, &c. and then work in all reſpects as above. *See the ſecond Example following.*

EXAMPLE

EXAMPLE I.

Required the Sun's true place, March 20*th*, *Old Stile*, 1764, *at* 22 *hours* 30 *minutes* 25 *seconds past noon?—In common reckoning*, March 21*st*, *at* 10 *hours* 30 *minutes* 25 *seconds in the forenoon.*

		Sun's Longitude.				Sun's Anomaly.			
		s	°	′	″	s	°	′	″
To the radical year after Christ — — —	1701	9	20	43	50	6	13	1	0
Add compleat years — — — — — —	60	0	0	27	12	11	29	26	0
	3	11	29	17	0	11	29	14	0
	March	1	28	9	11	1	28	9	0
Bissextile, Days — —	20		20	41	55		20	41	55
Hours — —	22			54	13			54	13
Minutes —	30			1	14			1	14
Seconds —	25				1				1
Sun's mean place at the given time — — — —		0	10	14	36	9	1	27	23
Equation of the Sun's center, add — — — —			1	55	36	Mean Anomaly.			
Sun's true place at the same time — — — —		0	12	10	12	or ♈ 12	10	12	

EXAMPLE

EXAMPLE II.

Required the Sun's true place, October 23*d*, *Old Stile, at* 16 *hours* 57 *minutes past noon, in the* 4008*th year before the year of Christ* 1; *which was the* 4007*th before the year of his birth, and the year of the* Julian *period* 706?

By the Precepts.

		Sun's Longitude.				Sun's Anomaly.			
		s	°	′	″	s	°	′	″
From the radical numbers after Christ — — —	1	9	7	53	10	6	28	48	0
Subtract those for 5000 compleat years — — —		1	7	46	40	10	13	25	0
Remains, for a new radix		8	0	6	30	8	15	23	0
To which add, to bring it to the given time: compleat years — — —	900	0	6	48	0	11	21	37	0
	80	0	0	36	16	11	29	15	0
	12	0	0	5	26	11	29	53	0
	October	8	29	4	54	8	29	4	0
Days	23		22	40	12		22	40	12
Hours	16			39	26			39	26
Minutes	57			2	20			2	20
Sun's mean place at the given time — — — —		6	0	3	4	5	28	33	58
Equation of the Sun's center subtract — — — —				3	4	Sun's Anomaly.			
Sun's true place at the same time — — — —		6	0	0	0 or ♎	0	0	0	

So that in the meridian of *London*, the Sun was then juſt entering the ſign ♎ *Libra*, and conſequently was upon the point of the Autumnal Equinox.

If to the above time of the Autumnal Equinox at *London*, we add 2 hours, 25 minutes 41 ſeconds for the longitude of *Babylon*, we ſhall have for the time of the ſame Equinox, at that place, *October* 23d, at 19 hours, 22 minutes 41 ſeconds; which in the common way of reckoning, is *October* 24th, at 22 minutes 41 ſeconds paſt VII in the morning*.

And it appears by Example VI. that in the ſame year, the true time of Full Moon at *Babylon* was *October* 23d, at 42 minutes 46 ſeconds after VI in the morning; ſo that the Autumnal Equinox was on the day next after the day of Full Moon.—The Dominical letter for that year was *G*, and conſequently the 24th of *October* was on a *Wedneſday*.

* The reaſon why this calculation makes the Autumnal Equinox, in the year of the *Julian Period* 706, to be two days ſooner than the time of the ſame Equinox mentioned in page 153 is, that in *that* page, only the mean time is taken into the account, as if there was no Equation of the Sun's motion.

The Equation at the Autumnal Equinox then, did not exceed an hour and a quarter, when reduced to time.—But, in the year of Chriſt 1756 (which was 5763 years after) the Equation at the Autumnal Equinox amounted to 1 day 22 hours 24 minutes, by which quantity, the true time fell later than the mean.—So that, if we conſider the *true* time of this laſt-mentioned Equinox, only as *mean* time, the mean Motion of the Sun carried thence back to the Autumnal Equinox in the year of the *Julian Period* 706, will fix it to the 25th of *October* in that year.

To find the Sun's distance from the Moon's ascending Node, at the time of any given New or Full Moon; and consequently, to know whether there is an Eclipse at that time, or not.

The Sun's distance from the Moon's ascending Node is the argument for finding the Moon's fourth Equation in the Syzygies, and therefore it is taken into all the foregoing Examples in finding the times thereof.—Thus, at the time of mean New Moon in *April* 1764, the Sun's mean Distance from the ascending Node, is $0^s\ 5^\circ\ 35'\ 2'$. *See Example* I. p. 306.

The descending Node is opposite to the ascending one, and they are just six Signs distant from each other.

When the Sun is within 17 degrees of either of the Nodes at the time of New Moon, he will be eclipsed at that time: and when he is within 12 degrees of either of the Nodes at the time of Full Moon, the Moon will be then eclipsed.—Thus we find, that there will be an Eclipse of the Sun at the time of New Moon in *April* 1764.

But the true time of that New Moon comes out by the Equations to be 50 minutes 46 seconds later than the mean Time thereof, by comparing these times in the above Example: and therefore, we must add the Sun's motion from the Node during that interval, to the above mean Distance $0^s\ 5^\circ\ 35'\ 2''$, which motion is found in Table XII. for 50 minutes 46 seconds, to be $2'\ 12''$. And to this we must apply the Equation of the Sun's mean Distance from the Node, in Table XV. found by the Sun's anomaly, which, at the mean time of New Moon in Example I. is $9^s\ 1^\circ\ 26'\ 19''$; and then we shall have the Sun's true Distance from the Node, at the true time of New Moon, as follows:

At

	Sun from Node s ° ′ ″
At the mean time of New Moon in *April* 1764 — — — —	0 5 35 2
Sun's motion from the Node for — — { 50 minutes	2 10
46 seconds	2
Sun's mean Diftance from Node at true New Moon — — —	0 5 37 14
Equation of mean Diftance from Node, add — — — —	2 5 0
Sun's true Diftance from the afcending Node — — —	0 7 42 14

Which, being far within the above limit of 17 degrees, fhews that the Sun muft then be eclipfed.

And now we fhall fhew how to project this, or any other eclipfe, either of the Sun or Moon.

To project an Eclipfe of the Sun.

In order to this, we muft find the ten following Elements, by means of the Tables.

1. The true time of conjunction of the Sun and Moon; and at that time, 2. The femidiameter of the Earth's difc, as feen from the Moon, which is equal to the Moon's horizontal parallax. 3. The Sun's diftance from the folftitial Colure to which he is then neareft. 4. The Sun's declination. 5. The angle of the Moon's vifible path with the Ecliptic. 6. The Moon's latitude. 7. The Moon's true horary motion from the Sun. 8. The Sun's femidiameter. 9. The Moon's. 10. The femidiameter of the Penumbra.

We fhall now proceed to find thefe Elements for the Sun's Eclipfe in *April* 1764.

To find the true time of New Moon. This, by Example I. pag. 306, is found to be on the firft day of the faid month, at 30 minutes 25 feconds after X in the morning.

2. *To find the Moon's horizontal parallax, or semi-diameter of the Earth's disc, as seen from the Moon.* Enter Table XVII. with the signs and degrees of the Moon's anomaly (making proportions, because the Anomaly is in the Table only to every 6th degree) and thereby take out the Moon's horizontal parallax; which, for the above time, answering to the Anomaly $11^s\ 9^\circ\ 24'\ 21''$, is $54'\ 53''$.

3. *To find the Sun's distance from the nearest Solstice, viz. the beginning of Cancer, which is 3^s or 90° from the beginning of Aries.* It appears by the Example on page 314 (where the Sun's place is calculated to the above time of New Moon) that the Sun's longitude from the beginning of Aries is then $0^s\ 12^\circ\ 10'\ 12''$: that is, the Sun's place at that time is ♈ Aries, $12^\circ\ 10'\ 12''$.

	s	°	′	″
Therefore from — — — —	3	0	0	0
Subtract the Sun's longitude or place	0	12	10	12
Remains the Sun's distance from the Solstice ♋ — — — =	2	17	49	48

Or $77^\circ\ 49'\ 48'$; each sign containing 30 degrees.

4. *To find the Sun's declination.* Enter Table XIV. with the signs and degrees of the Sun's true place, viz. $0^s\ 12^\circ$, and making proportions for the $10'\ 12''$, take out the Sun's declination answering to his true place, and it will be found to be $4^\circ\ 49'$ north.

5. *To find the Moon's latitude.* This depends on her distance from her ascending Node, which is the same as the Sun's distance from it at the time of New Moon; and is thereby found in Table XVI.

But we have already found, that the Sun's equated distance from the ascending Node, at the time of New Moon in *April* 1764, is $0^s\ 7^\circ\ 42'\ 14''$. *See the preceding page.*

Therefore, enter Table XVI. with 0 signs at the top, and 7 and 8 degrees at the left hand, and take out $36'$ and $39''$, the latitude for 7°; and

41′

41′ 51″, the latitude for 8°: and by making proportions between these latitudes for the 42′ 14″, by which the Moon's distance from the Node exceeds 7 degrees; her true Latitude will be found to be 40′ 18″ north ascending.

6. *To find the Moon's true horary motion from the Sun.* With the Moon's anomaly, viz. $11^s\ 9°\ 24′\ 21″$, enter Table XVII. and take out the Moon's horary motion; which, by making proportions in that Table, will be found to be 30′ 22″. Then, with the Sun's anomaly, $9^s\ 1°\ 26′\ 19″$, take out his horary motion 2′ 28″ from the same Table: and subtracting the latter from the former, there will remain 27′ 54″ for the Moon's true horary motion from the Sun.

7. *To find the angle of the Moon's visible path with the Ecliptic.* This, in the projection of Eclipses, may be always rated at 5° 35′, without any sensible error.

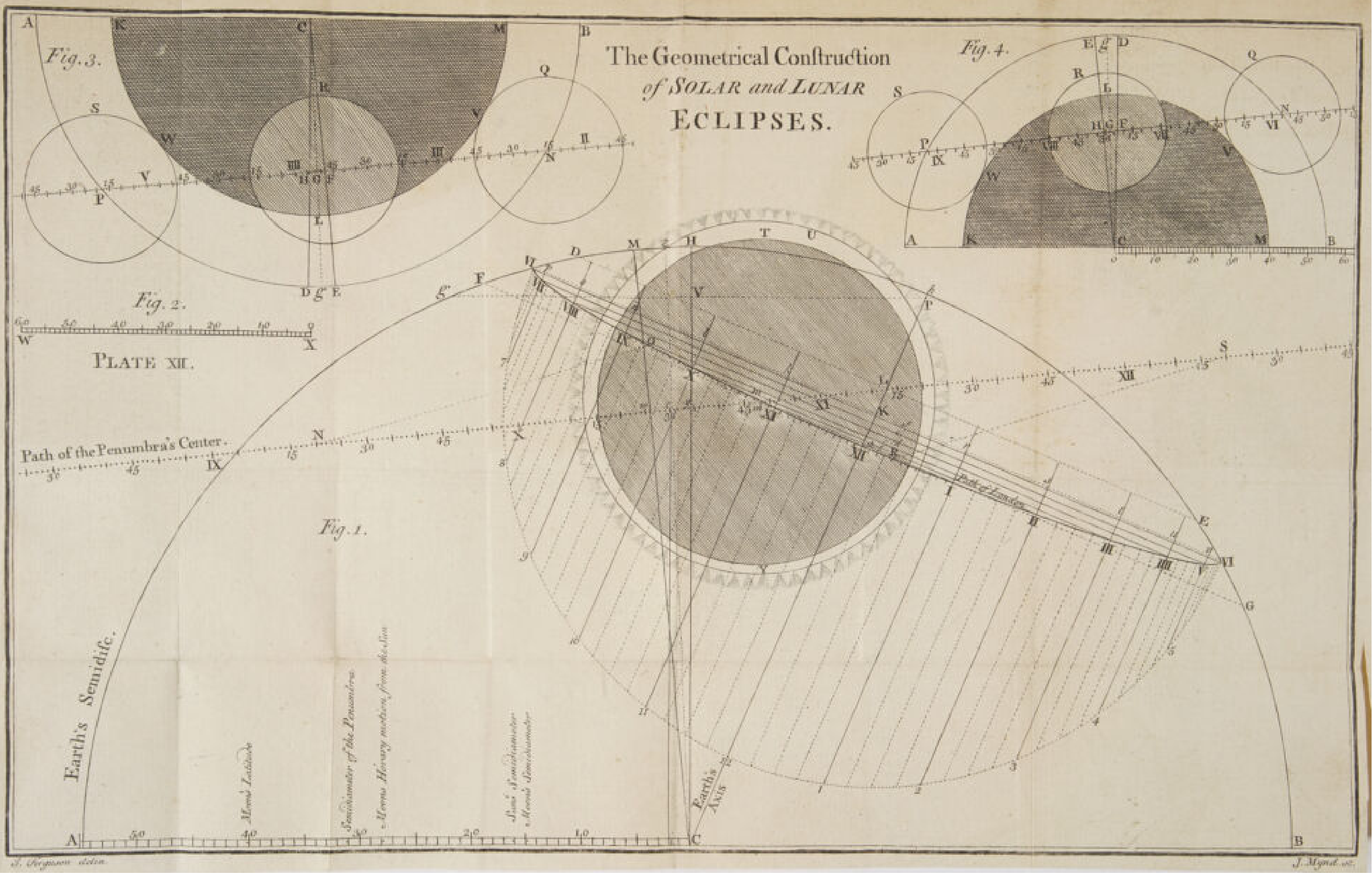
8, 9. *To find the semidiameters of the Sun and Moon.* These are found in the same Table, and by the same Arguments, as their horary Motions. —In the present case, the Sun's anomaly gives his semidiameter 16′ 6″, and the Moon's anomaly gives her semidiameter 14′ 57″.

10. *To find the semidiameter of the Penumbra.* Add the Moon's semidiameter to the Sun's, and their sum will be the semidiameter of the Penumbra, viz. 31′ 3″.

Now collect these Elements, that they may be found the more readily when they are wanted in the construction of this Eclipse.

1. True time of New Moon in *April*, 1764 — — — —	1	10	30	25
		°	″	′
2. Semidiameter of the Earth's disc		0	54	53
3. Sun's distance from the nearest Solst.		77	49	48
4. Sun's declination, north		4	49	0
5. Moon's latitude, north ascending		0	40	18

6. Moon's


The Geometrical Construction
of SOLAR and LUNAR
ECLIPSES.
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
PLATE XII.
Path of the Penumbra's Center.
Path of London
Earth's Semidisc.
Earth's Axis
Moon's Latitude
Semidiameter of the Penumbra
Moons Horary motion from the Sun
Sun's Semidiameter
Moons Semidiameter
J. Ferguson delin.
J. Mynd sc.

6. Moon's horary motion from the Sun	0	27	54
7. Angle of the Moon's visible path with the Ecliptic	5	35	0
8. Sun's semidiameter		16	6
9. Moon's semidiameter		14	57
10. Semidiameter of the Penumbra		31	3

To project an Eclipse of the Sun geometrically.

Make a scale of any convenient length, as *AC*, and divide it into as many equal parts as the Earth's semi-disc contains minutes of a degree; which, at the time of the Eclipse in *April* 1764, is 54′ 53″. Then, with the whole length of the scale as a radius, describe the semicircle *AMB* upon the center *C*; which semicircle shall represent the northern half of the Earth's enlightened disc, as seen from the Sun. PLATE XII. Fig. I.

Upon the center *C* raise the straight line *CH*, perpendicular to the diameter *ACB*; so *ACB* shall be a part of the Ecliptic, and *CH* its Axis.

Being provided with a good sector, open it to the radius *CA* in the line of chords; and taking from thence the chord of $23\frac{1}{2}$ degrees in your compasses, set it off both ways from *H*, to *g* and to *h*, in the periphery of the semi-disc; and draw the straight line *g V h*, in which the North Pole of the Disc will be always found.

When the Sun is in Aries, Taurus, Gemini, Cancer, Leo, and Virgo, the North Pole of the Earth is enlightened by the Sun: but whilst the Sun is in the other six Signs, the South Pole is enlightened, and the North Pole is in the dark.

And when the Sun is in Capricorn, Aquarius, Pisces, Aries, Taurus, and Gemini, the northern half of the Earth's axis *C* XII *P* lies to the right hand of the Axis of the Ecliptic, as seen from the Sun; and to the left hand, whilst the Sun is in the other six Signs.

Open the ſector till the radius (or diſtance of the two 90's) of the ſines be equal to the length of *V h*, and take the ſine of the Sun's diſtance from the Solſtice (77° 49′ 48″) as nearly as you can gueſs, in your compaſſes, from the line of ſines, and ſet off that diſtance from *V* to *P* in the line *g V h*, becauſe the Earth's axis lies to the right hand of the Axis of the Ecliptic in this caſe, the Sun being in Aries; and draw the ſtraight line *C* XII *P* for the Earth's axis, of which *P* is the North Pole. If the Earth's axis had lain to the left hand from the axis of the Ecliptic, the diſtance *V P* would have been ſet off from *V* towards *g*.

To draw the Parallel of Latitude of any given place, as ſuppoſe *London*, or the path of that place on the Earth's enlightened diſc as ſeen from the Sun, from Sun-riſe till Sun-ſet, take the following method.

Subtract the Latitude of *London*, 51°½ from 90°, and the remainder 38°½ will be the co-latitude, which take in your compaſſes from the line of chords, making *C A* or *C B* the radius, and ſet it from *h* (where the Earth's axis meets the Periphery of the Diſc) to VI and VI, and draw the occult or dotted line VI *K* VI. Then, from the points where this line meets the Earth's diſc, ſet off the chord of the Sun's declination 4° 49′ to *D* and *F*, and to *E* and *G*, and connect theſe points by the two occult lines *F* XII *G* and *D L E*.

Biſect *L K* XII in *K*, and through the point *K* draw the black line VI *K* VI. Then making *C B* the radius of a line of ſines on the ſector, take the co-latitude of *London* 38°½ from the ſines in your compaſſes, and ſet it both ways from *K*, to VI and VI.—Theſe hours will be juſt in the edge of the Diſc at the Equinoxes, but at no other time in the whole year.

With the extent *K* VI taken into your compaſſes, ſet one foot in *K* (in the black line below the occult one) as a center, and with the other foot

deſcribe

discribe the ſemicircle VI 7 8 9 10, &c. and divide it into 12 equal parts. Then, from theſe points of diviſion, draw the occult lines *7 p*, *8 o*, *9 n*, &c. parallel to the Earth's axis *C* XII *P*.

With the ſmall extent *K* XII as a radius, deſcribe the quadrantal Arc XII *f*, and divide it into ſix equal parts, as XII *a*, *a b*, *b c*, *c d*, *d e*, and *e f*; and through the diviſion-points *a*, *b*, *c*, *d*, *e* draw the occult lines VII *e* V, VIII *d* IV, IX *c* III, X *b* II, and XI *a* I; all parallel to VI *K* VI, and meeting the former occult lines *7 p*, *8 o*, &c. in the points VII VIII IX X XI, V IV III II and I: which points ſhall mark the ſeveral ſituations of *London* on the Earth's diſc, at theſe hours reſpectively, as ſeen from the Sun; and the elliptic Curve VI VII VIII, &c. being drawn through theſe points, ſhall repreſent the parallel of latitude, or path of *London* on the Diſc, as ſeen from the Sun, from it's riſing to it's ſetting.

N. B. If the Sun's declination had been ſouth, the diurnal path of *London* would have been on the upper ſide of the line VI *K* VI, and would have touched the line *D L E* in *L*.—It is requiſite to divide the horary ſpaces into quarters (as ſome are in the figure) and, if poſſible, into minutes alſo.

Make *C B* the radius of a line of chords on the ſector, and taking therefrom the chord of 5° 35′, the angle of the Moon's viſible path with the Ecliptic, ſet it off from *H* to *M* on the left hand of *C H*, the Axis of the Ecliptic, becauſe the Moon's latitude is north aſcending. Then draw *C M* for the Axis of the Moon's orbit, and biſect the angle *M C H* by the right-line *C z*.—If the Moon's latitude had been north deſcending, the Axis of her Orbit would have been on the right hand from the Axis of the Ecliptic.——*N. B.* The Axis of the Moon's orbit lies the ſame way when her Latitude is ſouth aſcending, as when it is north aſcending; and the ſame way when ſouth deſcending, as when north deſcending.

Take the Moon's latitude 40′ 18″ from the scale CA in your compasses, and set it from i to x in the bisecting line Cz, making ix parallel to Cy: and through x, at right-angles to the Axis of the Moon's orbit CM, draw the straight line $NwxyS$ for the path of the Penumbra's center over the Earth's disc.—The point w, in the Axis of the Moon's orbit, is that where the Penumbra's center approaches nearest to the center of the Earth's disc, and consequently is the middle of the general Eclipse: the point x is that where the conjunction of the Sun and Moon falls, according to equal time by the Tables; and the point y is the ecliptical conjunction of the Sun and Moon.

Take the Moon's true horary motion from the Sun, 27′ 54″, in your compasses, from the scale CA (every division of which is a minute of a degree) and with that extent make marks along the path of the Penumbra's center; and divide each space, from mark to mark, into 60 equal parts or horary minutes, by dots; and set the hours to every 60th minute in such a manner, that the dot signifying the instant of New Moon by the Tables, may fall into the point x, half way between the Axis of the Moon's orbit, and the Axis of the Ecliptic; and then, the rest of the dots will shew the points of the Earth's disc, where the Penumbra's center is at the instants denoted by them, in it's Transit over the Earth.

Apply one side of a square to the line of the Penumbra's path, and move the square backwards and forwards, until the other side of it cuts the same hour and minute (as at m and m) both in the path of *London*, and in the path of the Penumbra's center: and the particular minute or instant which the square cuts at the same time in both paths, shall be the instant of the visible conjunction of the Sun and Moon, or greatest obscuration of the Sun, at the place for which the construction is made, namely, *London*, in the present example; and this inſtant is at 47½ minutes paſt X o'clock in the morning; which is 17 minutes 5 ſeconds later than the tabular time of true conjunction.

Take the Sun's ſemidiameter, 16′ 6″, in your compaſſes, from the ſcale *C A*, and ſetting one foot in the path of *London* at *m*, namely, at 47½ minutes paſt X, with the other foot deſcribe the circle *U Y*, which ſhall repreſent the Sun's diſc as ſeen from *London* at the greateſt obſcuration.—Then take the Moon's ſemidiameter, 14′ 57″, in your compaſſes from the ſame ſcale; and ſetting one foot in the path of the Penumbra's center at *m*, in the 47½ minute after X; with the other foot deſcribe the circle *T Y* for the Moon's diſc, as ſeen from *London*, at the time when the Eclipſe is at the greateſt; and the portion of the Sun's diſc which is hid or cut off by the Moon's, will ſhew the quantity of the Eclipſe at that time; which quantity may be meaſured on a line equal to the Sun's diameter, and divided into twelve equal parts for digits.

Laſtly, take the ſemidiameter of the Penumbra, 31′ 3″, from the ſcale *C A* in your compaſſes; and ſetting one foot in the line of the Penumbra's central path, on the left hand from the Axis of the Ecliptic, direct the other foot toward the path of *London*; and carry that extent backwards and forwards, till both the points of the compaſſes fall into the ſame inſtants in both the parhs: and theſe inſtants will denote the time when the Eclipſe begins at *London*.—Then, do the like on the right hand of the Axis of the Ecliptic; and where the points of the compaſſes fall into the ſame inſtants in both the paths, they will ſhew at what time the Eclipſe ends at *London*.

Theſe trials give 20 minutes after IX in the morning for the beginning of the Eclipſe at *London*, at the points *N* and *O*; 47½ minutes after X, at the points *m* and *n*, for the time of greateſt obſcuration; and 18 minutes after XII, at *R* and *S*, for

 the

the time when the Eclipſe ends; according to mean or equal time.

From theſe times we muſt ſubtract the equation of natural days, viz. 3 minutes 48 ſeconds, in Leap-year *April* 1, and we ſhall have the apparent times; namely, IX hours 16 minutes 12 ſeconds for the beginning of the Eclipſe, X hours 43 minutes 42 ſeconds for the time of greateſt obſcuration, and XII hours 14 minutes 12 ſeconds for the time when the Eclipſe ends.—But the beſt way is to apply this Equation to the true equal time of New Moon, before the projection be begun; as is done in Example I. For the motion or poſition of places on the Earth's diſc anſwer to apparent or ſolar time.

In this conſtruction it is ſuppoſed, that the angle under which the Moon's diſc is ſeen, during the whole time of the Eclipſe, continues invariably the ſame; and that the Moon's motion is uniform and rectilineal during that time.—But theſe ſuppoſitions do not exactly agree with the truth; and therefore, ſuppoſing the Elements given by the Tables to be accurate, yet the times and phaſes of the Eclipſe, deduced from its conſtruction, will not anſwer to exactly to what paſſeth in the Heavens; but may be at leaſt two or three minutes wrong, though done with the greateſt care.—Moreover, the paths of all places of conſiderable latitudes are nearer the center of the Earth's diſc, as ſeen from the Sun, than thoſe conſtructions make them; becauſe the Diſc is projected as if the Earth were a perfect ſphere, although it is known to be a ſpheriod. Conſequently, the Moon's ſhadow will go farther northward in all places of northern latitude, and farther ſouthward in all places of ſouthern latitude, than it is ſhewn to do in theſe projections.—According to *Meyer*'s Tables, this Eclipſe will be about a quarter of an hour ſooner than either theſe Tables, or Mr. *Flamſteed*'s, or Dr. *Halley*'s make

it:

it: and will not be annular at *London*. But M. *De la Caille*'s make it almoſt central.

The projection of Lunar Eclipſes.

When the Moon is within 12 degrees of either of her Nodes, at the time when ſhe is full, ſhe will be eclipſed, otherwiſe not.

We find by Example II, page 307, that at the time of mean Full Moon in *May* 1762, the Sun's diſtance from the aſcending Node was only 4° 49′ 35″; and the Moon being then oppoſite to the Sun, muſt have been juſt as near her deſcending Node, and was therefore eclipſed.

The elements for conſtructing an Eclipſe of the Moon, are eight in number, as follow:

1. The true time of Full Moon: and at that time, 2. The Moon's horizontal parallax. 3. The Sun's ſemidiameter. 4. The Moon's. 5. The ſemidiameter of the Earth's ſhadow at the Moon. 6. The Moon's latitude. 7. The angle of the Moon's viſible path with the Ecliptic. 8. The Moon's true horary motion from the Sun.—— Therefore,

1. *To find the true time of Full Moon.* Work as already taught in the Precepts.—Thus we have the true time of Full Moon in *May* 1762 (See Example II. page 307) on the 8th day, at 50 minutes 50 ſeconds paſt III o'clock in the morning.

2. *To find the Moon's horizontal parallax.* Enter Table XVII. with the Moon's mean Anomaly (at the above full) 9ˢ 2° 42′ 42″, and thereby take out her horizontal Parallax; which, by making the requiſite proportions, will be found to be 57′ 23″.

3, 4. *To find the ſemidiameters of the Sun and Moon.* Enter Table XVII. with their reſpective Anomalies, the Sun's being 10ˢ 7° 27′ 45″ (by the above Example) and the Moon's 9ˢ 2° 42′ 42″; and thereby take out their reſpective ſemidiameters: the Sun's 15′ 56″; and the Moon's 15′ 38″.

5. *To find the semidiameter of the Earth's shadow at the Moon.* Add the Sun's horizontal parallax, which is always 10″, to the Moon's, which in the present case is 57′ 23″, the sum will be 57′ 33″, from which subtract the Sun's semidiameter 15′ 56″, and there will remain 41′ 37″ for the semidiameter of that part of the Earth's shadow which the Moon then passes through.

6. *To find the Moon's latitude.* Find the Sun's true distance from the ascending Node (as already taught in page 317) at the true time of Full Moon; and this distance increased by six signs, will be the Moon's true distance from the same Node; and consequently the argument for finding her true latitude, as shewn in page 319.

Thus, in Example II. the Sun's mean distance from the ascending Node was 0ˢ 4° 49′ 35″, at the time of mean Full Moon: but it appears by the Example, that the true time thereof was 6 hours 33 minutes 38 seconds sooner than the mean time, and therefore we must subtract the Sun's motion from the Node (found in Table XII. page 298) during this interval, from the above mean distance, 0ˢ 4° 49′ 35″, in order to have his mean distance from it at the true time of Full Moon.—Then to this apply the Equation of his mean distance from the Node, found in Table XV. by his mean Anomaly 10ˢ 7° 27′ 45″; and lastly add six signs: so shall the Moon's true distance from the ascending Node be found as follows:

		s	°	′	″
Sun from Node at mean Full Moon		0	4	49	35
His motion from it in	6 hours			15	35
	33 minutes			1	26
	38 seconds				2
Sum, subtract from the uppermost line				17	3
Remains his mean Distance at true Full Moon — — — —		0	4	32	32

Equation

	s	°	′	″
Equation of his mean Diſtance, add		1	38	0
Sun's true Diſtance from the Node	0	6	10	32
To which add	6	0	0	0
And the ſum will be	6	6	10	32

Which is the Moon's true diſtance from her aſcending Node at the true time of her being Full; and conſequently the Argument for finding her true Latitude at that time.—Therefore, with this argument, enter Table XVI. making proportions between the latitudes belonging to the 6th and 7th degree of the argument at the left hand (the ſigns being at the top) for the 10′ 32″, and it will give 32′ 21″ for the Moon's true latitude, which appears by the Table to be ſouth deſcending.

7. *To find the angle of the Moon's viſible path with the Ecliptic.* This may be ſtated at 5° 35′, without any error of conſequence in the projection of the Eclipſe.

8. *To find the Moon's true horary motion from the Sun.* With their reſpective Anomalies take out their horary motions from Table XVII. in page 302; and the Sun's horary motion ſubtracted from the Moon's, leaves remaining the Moon's true horary motion from the Sun: in the preſent caſe 30′ 52″.

Now collect theſe Elements together for uſe.

	D.	H.	M.	S.
1. True time of Full Moon in *May*, 1762	8	3	50	50
		°	′	″
2. Moon's horizontal Parallax		0	57	23
3. Sun's ſemidiameter		0	15	56
4. Moon's ſemidiameter		0	15	38
5. Semidiameter of the Earth's ſhadow at the Moon		0	41	37

6. Moon's

	°	′	″
6. Moon's true latitude, South defcending	0	32	21
7. Angle of her vifible path with the Ecliptic		5	35	0
8. Her true horary motion from the Sun	0	30	52

PLATE XII. These Elements being found for the conftruction of the Moon's Eclipfe in *May*, 1762, proceed as follows:

Fig. II. Make a fcale of any convenient length, as *W X*, and divide it into 60 equal parts, each part ftanding for a minute of a degree.

Draw the right line *ACB* (Fig. 3.) for part of the Ecliptic, and *C D* perpendicular thereto for the fouthern part of it's Axis; the Moon having fouth latitude.

Add the femidiameters of the Moon and Earth's fhadow together, which, in this Eclipfe, will make 57′ 15″; and take this from the fcale in your compaffes, and fetting one foot in the point *C* as a center, with the other foot defcribe the femicircle *A D B*; in one point of which the Moon's center will be at the beginning of the Eclipfe, and in another at the end thereof.

Take the femidiameter of the Earth's fhadow, 41′ 37″, in your compaffes from the fcale, and fetting one foot in the center *C*, with the other foot defcribe the femicircle *K L M* for the fouthern half of the Earth's fhadow, becaufe the Moon's latitude is fouth in this Eclipfe.

Make *C D* equal to the radius of a line of chords on the fector, and fet off the angle of the Moon's vifible path with the Ecliptic, 5° 35′, from *D* to *E*, and draw the right line *CFE* for the fouthern half of the Axis of the Moon's Orbit, lying to the right hand from the Axis of the Ecliptic *C D*, becaufe the Moon's latitude is fouth defcending.— It would have been the fame way (on the other fide of the Ecliptic) if her Latitude had been north defcending; but contrary in both cafes, if her

her Latitude had been either north aſcending or ſouth aſcending.

Biſect the angle *DCE* by the right line *Cg*; in which line, the true equal time of oppoſition of the Sun and Moon falls, as given by the Tables.

Take the Moon's latitude, 32′ 21″, from the ſcale with your compaſſes, and ſet it from *C* to *G*, in the line *CGg*; and through the point *G*, at right angles to *CFE*, draw the right line *PHGFN* for the path of the Moon's center.—Then, *F* ſhall be the point in the Earth's ſhadow, where the Moon's center is at the middle of the Eclipſe; *G*, the point where her center is at the tabular time of her being full; and *H*, the point where her center is at the inſtant of her ecliptical oppoſition.

Take the Moon's horary motion from the Sun, 30′ 52″, in your compaſſes from the ſcale; and with that extent make marks along the line of the Moon's path *PGN*: then divide each ſpace from mark to mark, into 60 equal parts, or horary minutes, and ſet the hours to the proper dots in ſuch a manner, that the dot ſignifying the inſtant of Full Moon (viz. 50 minutes 50 ſeconds after III in the morning) may be in the point *G*, where the line of the Moon's path cuts the line that biſects the angle *DCE*.

Take the Moon's ſemidiameter, 15′ 38″, in your compaſſes from the ſcale, and with that extent, as a radius, upon the points *N*, *F*, and *P*, as centers, deſcribe the circle *Q* for the Moon at the beginning of the Eclipſe, when ſhe touches the Earth's ſhadow at V; the circle *R* for the Moon at the middle of the Eclipſe; and the circle *S* for the Moon at the end of the Eclipſe, juſt leaving the Earth's ſhadow at *W*.

The point *N* denotes the inſtant when the Eclipſe begins, namely, at 15 minutes 10 ſeconds after II in the morning: the point *F* the middle of the Eclipſe at 47 minutes 45 ſeconds paſt III; and the point *P* the end of the Eclipſe, at 18 minutes after

after V.—At the greateſt obſcuration the Moon is 10 digits eclipſed.

Concerning an antient Eclipſe of the Moon.

It is recorded by *Ptolemy*, from *Hipparchus*, that on the 22d of *September*, the year 201 before the firſt year of Chriſt, the Moon roſe ſo much eclipſed at *Alexandria*, that the Eclipſe muſt have begun about half an hour before ſhe roſe.

Mr. *Carey* puts down this Eclipſe in his Chronology as follows, among ſeveral other antient ones, recorded by different authors.

Jul. Per. 4513 *Sept.* 22.	Ecl. ☾ *Per. Calip.* 2. *An.* 54. *Hor.* 7. *P. M. Alexandr. Dig. ecl.* 10. [*Ptolem. l.* 4. *c.* 11.]	*Nabonaſſar* 547 *Meſor.* 16.

That is, in the 4513th year of the *Julian* period, which was the 547th year from *Nabonaſſar*, and the 54th year of the ſecond *Calippic* period, on the 16th day of the month *Meſori* (which anſwers to the 22d of *September*) the Moon was 10 digits eclipſed at *Alexandria*, at 7 o'clock in the evening.

Now, as our Saviour was born (according to the *Dionyſian*, or vulgar Æra of his birth) in the 4713th year of the *Julian* period, it is plain that the 4513th year of that period was the 200th year before the year of Chriſt's birth; and conſequently 201 years before the year of Chriſt 1.

And, in the year 201, on the 22d of *September*, it appears by Example V. (page 310) that the Moon was full at 26 minutes 28 ſeconds paſt VII in the evening, in the meridian of *Alexandria*.

At that Time, the Sun's place was Virgo 26° 14′, according to our Tables; ſo that the Sun was then within 4 degrees of the Autumnal Equinox: and according to calculation, he muſt have ſet at *Alexandria* about 5 minutes after VI, and about one degree north of the weſt.

The

The Moon being full at that time, would have risen just at Sunset, about one degree south of the east, if she had been in either of her Nodes, and her visible place not depressed by Parallax.

But her parallactic depression (as appears from her Anomaly, viz. $10^s\ 6^\circ$ nearly) must have been $55'\ 17''$; which exceeded her whole diameter by $24'\ 53''$; but then, she must have been elevated $33'\ 45''$ by refraction; which subtracted from her Parallax, leaves $21'\ 32''$ for her visible or apparent depression.

And her true latitude was $30'\frac{1}{2}$ north descending, which being contrary to her apparent depression, and greater than the same by $8'\ 58''$, her true time of rising must have been just about VI o'clock.

Now, as the Moon rose about one degree south of the East at *Alexandria*, where the visible Horizon is land, and not sea, we can hardly imagine her to have been less than 15 or 20 minutes of time above the true Horizon before she was visible.

It appears by Fig. 4, which is a delineation of this Eclipse reduced to the time at *Alexandria*, that the Eclipse began at 53 minutes after V in the evening; and consequently 7 minutes before the Moon was in the true Horizon: to which, if we add 20 minutes for the interval between her true rising and her being visible, we shall have 27 minutes for the time that the Eclipse was begun before the Moon was visibly risen.—The middle of this Eclipse was at 30 minutes past VII, when it's quantity was almost 10 digits, and it's ending was at 6 minutes past IX in the evening.—So that our Tables come as near to the recorded time of this Eclipse as can be expected, after an elapse of 1960 years.

CHAP.

CHAP. XX.

Of the fixed Stars.

Why the fixed Stars appear bigger when viewed by the bare eye, than when seen thro' a telescope.

354. THE Stars are said to be fixed, because they have been generally observed to keep at the same distances from each other: their apparent diurnal revolutions being caused solely by the Earth's turning on it's Axis. They appear of a sensible magnitude to the bare eye, because the retina is affected not only by the rays of light which are emitted directly from them, but by many thousands more, which falling upon our eyelids, and upon the ærial particles about us, are reflected into our eyes so strongly, as to excite vibrations not only in those points of the retina where the real images of the Stars are formed, but also in other points at some distance round about. This makes us imagine the Stars to be much bigger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter our eyes without being intermixed with others. Any one may be sensible of this, by looking at a Star of the first magnitude through a long narrow tube; which, though it takes in as much of the sky as would hold a thousand such Stars, it scarce renders *that* one visible.

The more a telescope magnifies, the less is the aperture through which the Star is seen; and consequently the fewer rays it admits into the eye.

A proof that they shine by their own light.

Now since the Stars appear less in a telescope which magnifies 200 times than they do to the bare eye, insomuch that they seem to be only indivisible points, it proves at once that the Stars are at immense distances from us, and that they shine by their own proper light. If they shone by borrowed light, they would be as invisible without telescopes as the Satellites of Jupiter are: for these Satellites

Satellites appear bigger when viewed with a good teleſcope than the largeſt fixed Stars do.

355. The number of Stars diſcoverable, in either Hemiſphere, by the naked eye, is not above a thouſand. This at firſt may appear incredible, becauſe they ſeem to be without number: But the deception ariſes from our looking confuſedly upon them, without reducing them into any order. For look but ſtedfaſtly upon a pretty large portion of the ſky, and count the number of Stars in it, and you will be ſurpriſed to find them ſo few. And, if one conſiders how ſeldom the Moon meets with any Stars in her way, although there are as many about her Path as in other parts of the Heavens, he will ſoon be convinced that the Stars are much thinner ſown than he was aware of. The *Britiſh* catalogue, which, beſides the Stars viſible to the bare eye, includes a great number which cannot be ſeen without the aſſiſtance of a teleſcope, contains no more than 3000, in both Hemiſpheres.

Their number much leſs than is generally imagined.

356. As we have incomparably more light from the Moon than from all the Stars together, it is the greateſt abſurdity to imagine that the Stars were made for no other purpoſe than to caſt a faint light upon the Earth: eſpecially ſince many more require the aſſiſtance of a good teleſcope to find them out, than are viſible without that inſtrument. Our Sun is ſurrounded by a ſyſtem of Planets and Comets; all which would be inviſible from the neareſt fixed Star. And from what we already know of the immenſe diſtance of the Stars, the neareſt may be computed at 32,000,000,000,000 of miles from us, which is further than a cannon-bullet would fly in 7,000,000 of years. Hence it is eaſy to prove, that the Sun, ſeen from ſuch a diſtance, would appear no bigger than a Star of the firſt magnitude. From all this it is highly probable that each Star is a Sun to a ſyſtem of worlds moving round it, though unſeen by us; eſpecially, as the doctrine of purality of worlds is rational,

The abſurdity of ſuppoſing the Stars were made only to ſhine upon us in the night.

rational, and greatly manifests the Power, Wisdom, and Goodness of the great Creator.

Their different magnitudes.

357. The Stars, on account of their apparently various magnitudes, have been distributed into several classes or orders. Those which appear largest, are called *Stars of the first magnitude*; the next to them in lustre, *Stars of the second magnitude*; and so on to the *sixth*, which are the smallest that that are visible to the bare eye. This distribution having been made long before the invention of telescopes, the Stars which cannot be seen without the assistance of these instruments, are distinguished by the name of *Telescopic Stars*.

And division into Constellations.

358. The antients divided the starry Sphere into particular Constellations, or Systems of Stars, according as they lay near one another, so as to occupy those spaces which the figures of different sorts of animals or things would take up, if they were there delineated. And those Stars which could not be brought into any particular Constellation, were called *unformed Stars*.

The use of this division.

359. This division of the Stars into different Constellations or Asterisms, serves to distinguish them from one another, so that any particular Star may be readily found in the Heavens by means of a Celestial Globe; on which the Constellations are so delineated as to put the most remarkable Stars into such parts of the figures as are most easily distinguished. The number of the antient Constellations is 48, and upon our present Globes about 70. On *Senex's* Globes, *Bayer's* Letters are inserted; the first in the Greek Alphabet being put to the biggest Star in each Constellation, the second to the next, and so on; by which means, every Star is as easily found as if a name were given to it. Thus, if the Star γ in the Constellation of the *Ram* be mentioned, every Astronomer knows as well what Star is meant as if it were pointed out to him in the Heavens.

360. There

360. There is alſo a diviſion of the Heavens into three parts. 1. The *Zodiac* (ζωδίακος) from ζώδιον *Zodion* an Animal, becauſe moſt of the Conſtellations in it, which are twelve in number, are the figures of Animals: as *Aries* the Ram, *Taurus* the Bull, *Gemini* the Twins, *Cancer* the Crab, *Leo* the Lion, *Virgo* the Virgin, *Libra* the Balance, *Scorpio* the Scorpion, *Sagittarius* the Archer, *Capricornus* the Goat, *Aquarius* the Water-bearer, and *Piſces* the Fiſhes. The Zodiac goes quite round the Heavens: it is about 16 degrees broad, ſo that it takes in the Orbits of all the Planets, and likewiſe the Orbit of the Moon. Along the middle of this Zone or Belt is the Ecliptic, or Circle which the Earth deſcribes annually as ſeen from the Sun; and which the Sun appears to deſcribe as ſeen from the Earth. 2. All that Region of the Heavens, which is on the north ſide of the Zodiac, contains 21 Conſtellations. And 3. That on the ſouth ſide, 15. *The Zodiac.*

361. The antients divided the *Zodiac* into the above 12 Conſtellations or Signs in the following manner. They took a veſſel with a ſmall hole in in the bottom, and having filled it with water, ſuffered the ſame to diſtil drop by drop into another veſſel ſet beneath to receive it; beginning at the moment when ſome Star roſe, and continuing until it roſe the next following night. The water fallen down into the receiver they divided into twelve equal parts; and having two other ſmall veſſels in readineſs, each of them fit to contain one part, they again poured all the water into the upper veſſel, and obſerving the riſing of ſome Star in the *Zodiac*, they at the ſame time ſuffered the water to drop into one of the ſmall veſſels; and as ſoon as it was full, they ſhifted it, and ſet an empty one in it's place. When each veſſel was full, they took notice what Star of the *Zodiac* roſe; and though this could not be done in one night, yet in many, they *The manner of dividing it by the antients.*

 obſerved

obſerved the riſing of twelve Stars or points, by which they divided the *Zodiac* into twelve parts.

362. The names of the Conſtellations, and the number of Stars obſerved in each of them by different Aſtronomers, are as follows.

The antient Conſtellations.		*Ptolemy.*	*Tycho.*	*Hevel.*	*Flamſt.*
Urſa minor	The Little Bear	8	7	12	24
Urſa major	The Great Bear	35	29	73	87
Draco	The Dragon	31	32	40	80
Cepheus	Cepheus	13	4	51	35
Bootes, *Arctophilax*		23	18	52	54
Corona Borealis	The Northern Crown	8	8	8	21
Hercules, *Engonaſin*	Hercules kneeling	29	28	45	113
Lyra	The Harp	10	11	17	21
Cygnus, *Gallina*	The Swan	19	18	47	81
Caſſiepea	The Lady in her Chair	13	26	37	55
Perſeus	Perſeus	29	29	46	59
Auriga	The Waggoner	14	9	40	66
Serpentarius, *Ophiuchus*	Serpentarius	29	15	40	74
Serpens	The Serpent	18	13	22	64
Sagitta	The Arrow	5	5	5	18
Aquila, *Vultur*	The Eagle	15	12	23	71
Antinous	Antinous		3	19	
Delphinus	The Dolphin	10	10	14	18
Equulus, *Equi ſectio*	The Horſe's Head	4	4	6	10
Pegaſus, *Equus*	The Flying Horſe	20	19	38	89
Andromeda	Andromeda	23	23	47	66
Triangulum	The Triangle	4	4	12	16
Aries	The Ram	18	21	27	66
Taurus	The Bull	44	43	51	141
Gemini	The Twins	25	25	38	85
Cancer	The Crab	23	15	29	83
Leo	The Lion	35	30	49	95
Coma Berenices	Berenice's Hair		14	21	43
Virgo	The Virgin	32	33	50	110
Libra, *Chelæ*	The Scales	17	10	20	51
Scorpius	The Scorpion	24	10	20	44
Sagittarius	The Archer	31	14	22	69
Capricornus	The Goat	28	28	29	51
Aquarius	The Water-bearer	45	41	47	108
Piſces	The Fiſhes	38	36	39	113
Cetus	The Whale	22	21	45	97
Orion	Orion	38	42	62	78
Eridanus, *Fluvius*	Eridanus, *the River*	34	10	27	84
Lepus	The Hare	12	13	16	19
Canis major	The Great Dog	29	13	21	31
Canis minor	The Little Dog	2	2	13	14

The

The antient Constellations.		Ptolemy.	Tycho.	Hevelius.	Flamst.
Argo Navis	The Ship	45	3	4	64
Hydra	The Hydra	27	19	31	60
Crater	The Cup	7	3	10	31
Corvus	The Crow	7	4		9
Centaurus	The Centaur	37			35
Lupus	The Wolf	19			24
Ara	The Altar	7			9
Corona Auſtralis	The Southern Crown	13			12
Piſces Auſtralis	The Southern Fiſh	18			24

The New Southern Conſtellations.

Columba Noachi	Noah's Dove	10
Robur Carolinum	The Royal Oak	12
Grus	The Crane	13
Phœnix	The Phenix	13
Indus	The Indian	12
Pavo	The Peacock	14
Apus, *Avis Indica*	The Bird of Paradiſe	11
Apis, *Muſca*	The Bee or Fly	4
Chamæleon	The Chameleon	10
Triangulum Auſtralis	The South Triangle	5
Piſcis volans, *Paſſer*	The Flying Fiſh	8
Dorado, *Xiphias*	The Sword Fiſh	6
Toucan	The American Gooſe	9
Hydrus	The Water Snake	10

Hevelius's Conſtellations made out of the unformed Stars.

		Hevelius.	Flamſteed.
Lynx	The Lynx	19	44
Leo minor	The Little Lion		53
Aſteron & Chara	The Greyhounds	23	25
Cerberus	Cerberus	4	
Vulpecula & Anſer	The Fox and Gooſe	27	35
Scutum Sobieſki	Sobieſki's Shield	7	
Lacerta	The Lizard	10	16
Camelopardalus	The Camelopard	32	58
Monoceros	The Unicorn	19	31
Sextans	The Sextant	11	41

363. There is a remarkable track round the Heavens, called the *Milky Way* from it's peculiar whiteneſs, which was formerly thought to be owing to a vaſt number of very ſmall Stars therein: but the teleſcope ſhews it to be quite otherwiſe; and therefore it's whiteneſs muſt be owing to ſome *The Milky Way.*

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other cauſe. This track appears ſingle in ſome parts, in others double.

Lucid Spots. 364. There are ſeveral little whitiſh ſpots in the Heavens, which appear magnified, and more luminous when ſeen through teleſcopes; yet without any Stars in them. One of theſe is in *Andromeda*'s girdle, and was firſt obſerved *A. D.* 1612, by *Simon Marius*: it has ſome whitiſh rays near it's middle, is liable to ſeveral changes, and is ſometimes inviſible. Another is near the Ecliptic, between the head and bow of *Sagittarius*: it is ſmall, but very luminous. A third is on the back of the *Centaur*, which is too far South to be ſeen in *Britain*. A fourth, of a ſmaller ſize, is before *Antinous*'s right foot; having a Star in it, which makes it appear more bright. A fifth is in the Conſtellation of *Hercules*, between the Stars ζ and η, which ſpot, though but ſmall, is viſible to the bare eye if the Sky be clear and the Moon abſent.

Cloudy Stars. 365. *Cloudy Stars* are ſo called from their miſty appearance. They look like dim Stars to the naked eye; but through a teleſcope they appear broad illuminated parts of the ſky; in ſome of which is one Star, in others more. Five of theſe are mentioned by *Ptolemy*. 1. One at the extremity of the right hand of *Perſeus*. 2. One in the middle of the *Crab*. 3. One unformed, near the Sting of the *Scorpion*. 4. The eye of *Sagittarius*. 5. One in the head of *Orion*. In the firſt of theſe appear more Stars through the teleſcope than in any of the reſt, although 21 have been counted in the head of *Orion*, and above 40 in that of the *Crab*. Two are viſible in the eye of *Sagittarius* without a teleſcope, and ſeveral more with it. *Flamſteed* obſerved a cloudy Star in the bow of *Sagittarius*, containing many ſmall Stars: and the Star *d* above *Sagittarius*'s right ſhoulder is encompaſſed with ſeveral more. Both *Caſſini* and *Flamſteed* diſcovered one between the *Great* and *Little Dog*, which is very full of Stars viſible only by the teleſcope.

telescope. The two whitish spots near the South Pole, called the *Magellanic Clouds* by Sailors, which to the bare eye resemble part of the Milky Way, appear through telescopes to be a mixture of small Clouds and Stars. But the most remarkable of all the cloudy Stars is that in the middle of *Orion's Sword*, where seven Stars (of which three are very close together) seem to shine through a cloud, very lucid near the middle, but faint and ill defined about the edges. It looks like a gap in the sky, through which one may see (as it were) part of a much brighter region. Although most of these spaces are but a few minutes of a degree in breadth, yet, since they are among the fixed Stars, they must be spaces larger than what is occupied by our Solar System; and in which there seems to be a perpetual uninterrupted day among numberless Worlds, which no human art ever can discover.

Magellanic Clouds.

366. Several Stars are mentioned by antient Astronomers, which are not now to be found; and others are now visible to the bare eye which are not recorded in the antient catalogue. *Hipparchus* observed a new Star about 120 years before CHRIST; but he has not mentioned in what part of the Heavens it was seen, although it occasioned his making a Catalogue of the Stars; which is the most antient that we have.

Changes in the Heavens.

The first *New Star* that we have any good account of, was discovered by *Cornelius Gemma* on the 8th of *November* A. D. 1572, in the Chair of *Cassiepea*. It surpassed *Sirius* in brightness and magnitude; and was seen for 16 months successively. At first it appeared bigger than *Jupiter* to some eyes, by which it was seen at mid-day: afterwards it decayed gradually both in magnitude and lustre, until *March* 1573, when it became invisible.

New Stars.

On the 13th of *August* 1596, *David Fabricius* observed the *Stella Mira*, or wonderful Star, in the *Neck* of the *Whale*; which has been since found to appear and disappear periodically, seven times in ſix years, continuing in the greateſt luſtre for 15 days together; and is never quite extinguiſhed.

In the year 1600, *William Janſenius* diſcovered a changeable Star in the *Neck* of the *Swan*; which, in time, became ſo ſmall as to be thought to diſappear entirely, till the years 1657, 1658, and 1659, when it recovered it's former luſtre and magnitude; but ſoon decayed, and is now of the ſmalleſt ſize.

In the year 1604, *Kepler* and ſeveral of his friends ſaw a new Star near the heel of the right foot of *Serpentarius*, ſo bright and ſparkling, that it exceeded any thing they had ever ſeen before; and took notice that it was every moment changing into ſome of the colours of the rainbow, except when it was near the Horizon, at which time it was generally white. It ſurpaſſed *Jupiter* in magnitude, which was near it all the month of *October*, but eaſily diſtinguiſhed from *Jupiter*, by the ſteady light of that Planet. It diſappeared between *October* 1605 and the *February* following, and has not been ſeen ſince that time.

In the year 1670, *July* 15, *Hevelius* diſcovered a new Star, which in *October* was ſo decayed as to be ſcarce perceptible. In *April* following it regained it's luſtre, but wholly diſappeared in *Auguſt*. In *March* 1672 it was ſeen again, but very ſmall; and has not been viſible ſince.

In the year 1686 a new Star was diſcovered by *Kirch*, which returns periodically in 404 days.

In the year 1672, *Caſſini* ſaw a Star in the *Neck* of the *Bull*, which he thought was not viſible in *Tycho*'s time; nor when *Bayer* made his Figures.

Cannot be Comets.

367. Many Stars, beſides thoſe above-mentioned, have been obſerved to change their magnitudes: and as none of them could ever be perceived to have tails, it is plain they could not be Comets; eſpecially as they had no Parallax, even when largeſt and brighteſt. It would ſeem that the periodical Stars have vaſt cluſters of dark ſpots, and very

ſlow rotations on their Axis; by which means, they muſt diſappear when the ſide covered with ſpots is turned towards us. And as for thoſe which break out all of a ſudden with ſuch luſtre, it is by no means improbable that they are Suns whoſe Fuel is almoſt ſpent, and again ſupplied by ſome of their Comets falling upon them, and occaſioning an uncommon blaze and ſplendor for ſome time: which indeed appears to be the greateſt uſe of the cometary part of any ſyſtem *.

Some of the Stars, particularly *Arcturus*, have been obſerved to change their places above a minute of a degree with reſpect to others. But whether this be owing to any real motion in the Stars themſelves, muſt require the obſervations of many ages to determine. If our Solar Syſtem changeth it's Place, with regard to abſolute ſpace, this muſt in proceſs of time occaſion an apparent change in the diſtances of the Stars from each other: and in ſuch a caſe, the places of the neareſt Stars to us being more affected than thoſe which are very remote, their relative poſitions muſt ſeem to alter, though the Stars themſelves were really immoveable. On the other hand, if our own Syſtem be at reſt, and any of the Stars in real motion, this muſt vary their poſitions; and the more ſo, the nearer

Some Stars change there Places.

* M. *Maupertuis*, in his diſſertation on the figures of the Celeſtial Bodies (p. 61—63) is of opinion that ſome Stars, by their prodigious quick rotations on their Axes, may not only aſſume the figures of oblate ſpheroids, but that by the great centrifugal force, ariſing from ſuch rotations, they may become of the figures of mill-ſtones; or be reduced to flat circular planes, ſo thin as to be quite inviſible when their edges are turned towards us; as Saturn's Ring is in ſuch poſitions. But when very excentric Planets or Comets go round any flat Star, in Orbits much inclined to it's Equator, the attraction of the Planets or Comets in their Perihelions muſt alter the inclination of the Axis of that Star; on which account it will appear more or leſs large and luminous, as it's broad ſide is more or leſs turned towards us. And thus he imagines we may account for the apparent changes of magnitude and luſtre in thoſe Stars, and likewiſe for their appearing and diſappearing.

they are to us, or ſwifter their motions are; or the more proper the direction of their motion is, for our preception.

The Ecliptic leſs oblique now to the Equator than formerly.

368. The obliquity of the Ecliptic to the Equinoctial is found at preſent to be above the third part of a degree leſs than *Ptolemy* found it. And moſt of the obſervers after him found it to decreaſe gradually down to *Tycho*'s time. If it be objected, that we cannot depend on the obſervations of the antients, becauſe of the incorrectneſs of their Inſtruments; we have to anſwer, that both *Tycho* and *Flamſteed* are allowed to have been very good obſervers; and yet we find that *Flamſteed* makes this obliquely 2½ minutes of a degree leſs than *Tycho* did, about 100 years before him: and as *Ptolemy* was 1324 years before *Tycho*, ſo the gradual decreaſe anſwers nearly to the difference of time between theſe three Aſtronomers. If we conſider, that the Earth is not a perfect ſphere, but an oblate ſpheroid, having it's Axis ſhorter than it's equatorial diameter; and that the Sun and Moon are conſtantly acting obliquely upon the greater quantity of matter about the Equator, pulling it, as it were, towards a nearer and nearer co-incidence with the Ecliptic; it will not appear improbable that theſe actions ſhould gradually diminiſh the Angle between thoſe Planes. Nor is it leſs probable that the mutual attraction of all the Planets ſhould have a tendency to bring their Orbits to a co-incidence: but this change is too ſmall to become ſenſible in many ages.

CHAP.

CHAP. XXI.

Of the Division of Time. A perpetual Table of New Moons. The Times of the Birth and Death of CHRIST. *A Table of remarkable Æras or Events.*

369. THE parts of time are *Seconds*, *Minutes*, *Hours*, *Days*, *Years*, *Cycles*, *Ages*, and *Periods*.

370. The original ftandard, or integral meafure of Time, is a Year; which is determined by the Revolution of fome Celeftial Body in it's Orbit, viz. the *Sun* or *Moon*. A Year.

371. The time meafured by the Sun's Revolution in the Ecliptic, from any Equinox or Solftice to the fame again, is called the *Solar* or *Tropical Year*, which contains 365 days, 5 hours, 48 minutes, 57 feconds; and is the only proper or natural year, becaufe it always keeps the fame feafons to the fame months. Tropical Year.

372. The quantity of time, meafured by the Sun's Revolution as from any fixed Star to the fame Star again, is called the *Sydereal Year*; which contains 365 days, 6 hours, 9 minutes, 14½ feconds; and is 20 minutes, 17½ feconds longer than the true Solar Year. Sydereal Year.

373. The time meafured by twelve Revolutions of the Moon, from the Sun to the Sun again, is called the *Lunar Year*; it contains 354 days, 8 hours, 48 minutes, 36 feconds; and is therefore 10 days, 21 hours, 0 minutes, 21 feconds, fhorter than the Solar Year. This is the foundation of the Epact. Lunar Year.

374. The *Civil Year* is that which is in common ufe among the different nations of the world; of which, fome reckon by the Lunar, but moft by the Solar. The Civil Solar Year contains 365 days, for three years running, which are called *Common Years*; and then comes in what is called the *Biffex-* Civil Year.

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tile or *Leap-year*, which contains 366 days. This is alſo called the *Julian Year* on account of *Julius Cæſar*, who appointed the Intercalary-day every fourth year, thinking thereby to make the Civil and Solar Year keep pace together. And this day, being added to the 23d of *February*, which in the *Roman* Calendar was the ſixth of the Calends of *March*, that ſixth day was twice reckoned, or the 23d and 24th were reckoned as one day; and was called *Bis ſextus dies*, and thence came the name *Biſſextile* for that year. But in our common Almanacks this day is added at the end of *February*.

Lunar Year. 375. The *Civil Lunar Year*, is alſo common or intercalary. The common Year conſiſts of 12 Lunations, which contain 354 days; at the end of which, the year begins again. The *Intercalary*, or *Embolimic* Year, is that wherein a month was added, to adjuſt the Lunar Year to the Solar. This method was uſed by the *Jews*, who kept their account by the Lunar Motions. But by intercalating no more than a month of 30 days, which they called *Ve-Adar*, every third year, they fell $3\frac{3}{4}$ days ſhort of the Solar Year in that time.

Roman Year. 376. The *Romans* alſo uſed the *Lunar Embolimic Year* at firſt, as it was ſettled by *Romulus* their firſt King, who made it to conſiſt only of ten months or Lunations; which fell 61 days ſhort of the Solar Year, and ſo their year became quite vague and unfixed; for which reaſon, they were forced to have a Table publiſhed by the High-Prieſt, to inform them when the ſpring and other ſeaſons began. But *Julius Cæſar*, as already mentioned, § 374, taking this troubleſome affair into conſideration, reformed the Calendar, by making the year to conſiſt of 365 days, 6 hours.

The original of the *Gregorian*, or *New Stile*. 377. The year thus ſettled, is what we ſtill make uſe of in *Britain*: but as it is ſomewhat more than 11 minutes longer than the *Solar Tropical Year*, the times of the Equinoxes go backward, and fall earlier by one day in about 130 years. In the time of of the *Nicene Council* (A. D. 325) which was 1439 years ago, the Vernal Equinox fell on the 21st of *March*: and if we divide 1444 by 130, it will quote 11, which is the number of days the Equinox has fallen back since the Council of *Nice*. This causing great disturbances, by unfixing the times of the celebration of *Easter*, and consequently of all the other moveable Feasts, Pope *Gregory* the 13th, in the year 1582, ordered ten days to be at once struck out of that year; and the next day after the fourth of *October* was called the fifteenth. By this means the Vernal Equinox was restored to the 21st of *March*; and it was endeavoured, by the omission of three intercalary days in 400 years, to make the Civil or Political year keep pace with the Solar for time to come. This new form of the year is called the *Gregorian Account*, or *New Stile*; which is received in all Countries where the Pope's Authority is acknowledged, and ought to be in all places where truth is regarded.

378. The principal division of the year is into *Months*, which are of two sorts, namely, *Astronomical* and *Civil*. The Astronomical month is the time in which the Moon runs through the *Zodiac*, and is either *Periodical* or *Synodical*. The Periodical Month is the time spent by the Moon in making one complete Revolution from any point of the Zodiac to the same again; which is $27^{d}\ 7^{h}\ 43^{m}$. The Synodical Month, called a *Lunation*, is the time contained between the Moon's parting with the Sun at a Conjunction, and returning to him again; which is $29^{d}\ 12^{h}\ 44^{m}$. The Civil Months are those which are framed for the uses of civil life; and are different as to their names, number of days, and times of beginning, in several different Countries. The first month of the *Jewish Year* fell according to the Moon in our *August* and *September*, Old Stile; the second in *September* and *October*; and so on. The first month of the *Egyptian Year* began on the 29th of our *August*. The first month Months.

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of the *Arabic* and *Turkiſh Year* began the 16th of *July*. The firſt month of the *Grecian Year* fell according to the Moon in *June* and *July*, the ſecond in *July* and *Auguſt*, and ſo on, as in the following Table.

379. A month is divided into four parts called *Weeks*, and a Week into ſeven parts called *Days*; ſo that in a *Julian* year there are 13 ſuch Months, or 52 Weeks, and one Day over. The Gentiles gave the names of the Sun, Moon, and Planets, to the Days of the Week. To the firſt, the Name of the *Sun*; to the ſecond, of the *Moon*; to the third, of *Mars*; to the fourth, of *Mercury*; to the fifth, of *Jupiter*; to the ſixth, of *Venus*; and to the ſeventh, of *Saturn*.

N°	The *Jewiſh* year.		Days
1	Tiſri — — — —	Aug.—Sept.	30
2	Marcheſvan — —	Sept.—Oct.	29
3	Caſleau — — —	Oct. —Nov.	30
4	Tebeth — — —	Nov.—Dec.	29
5	Shebat — — —	Dec. —Jan.	30
6	Adar — — —	Jan. —Feb.	29
7	Niſan *or* Abib — —	Feb. —Mar.	30
8	Jiar — — —	Mar. —Apr.	29
9	Sivan — —	April—May	30
10	Tamuz — —	May —June	29
11	Ab — — —	June—July	30
12	Elul — — —	July —Aug.	29
	Days in the year — — — — —		354

In the *Embolimic* year after *Adar* they added a month called *Ve-Adar* of 30 days.

N°

N°	*The Egyptian* year.		Days
1	Thoth — — — August	29	30
2	Paophi — — — September	28	30
3	Athir — — — October	28	30
4	Chojac — — — November	27	30
5	Tybi — — — — December	27	30
6	Mechir — — — January	26	30
7	Phamenoth — — February	25	30
8	Parmuthi — — — March	27	30
9	Pachon — — — April	26	30
10	Payni — — — — May	26	30
11	Epiphi — — — June	25	30
12	Mesori — — — July	25	30
	Epagomenæ or days added — — —		5
	Days in the year — — — —		365

N°	The *Arabic* and *Turkish* year.		Days
1	Muharram — — — July	16	30
2	Saphar — — — August	15	29
3	Rabia I. — — — September	13	30
4	Rabia II. — — — October	13	29
5	Jomada I. — — — November	11	30
6	Jomada II. — — — December	11	29
7	Rajab — — — January	9	30
8	Shasban — — — February	8	29
9	Ramadam — — — March	9	30
10	Shawal — — — April	8	29
11	Dulhaadah — — — May	7	30
12	Dulheggia — — — June	5	29
	Days in the year — — — —		354

The *Arabians* add 11 days at the end of every year, which keep the same months to the same seasons

Nº	The ancient *Grecian* year.	Days
1	Hecatombæon — — June—July	30
2	Metagitnion — — July —Aug.	29
3	Boedromion — — Aug.—Sept.	30
4	Pyanepſion — — Sept.—Oct.	29
5	Maimacterion — — Oct. —Nov.	30
6	Poſideon — — — Nov.—Dec.	29
7	Gamelion — — — Dec.—Jan.	30
8	Antheſterion — — Jan.—Feb.	29
9	Elaphebolion — — Feb.—Mar.	30
10	Munichion — — — Mar.—Apr.	29
11	Thargelion — — Apr.—May	30
12	Schirrophorion — — May—June	29
	Days in the year — — — —	354

Days. 380. A *Day* is either *Natural* or *Artificial*. The Natural Day contains 24 hours; the Artificial, the time from Sun-riſe to Sun-ſet. The Natural Day is either *Aſtronomical* or *Civil*. The Aſtronomical Day begins at Noon, becauſe the increaſe and decreaſe of Days terminated by the Horizon are very unequal among themſelves; which inequality is likewiſe augmented by the inconſtancy of the horizontal Refractions § 183: and therefore the Aſtronomer takes the Meridian for the limit of diurnal Revolutions; reckoning Noon, that is, the inſtant when the Sun's Center is on the Meridian, for the beginning of the Day. The *Britiſh*, *French*, *Dutch*, *Germans*, *Spaniards*, *Portugueſe*, and *Egyptians*, begin the Civil Day at Midnight: the antient *Greeks*, *Jews*, *Bohemians*, *Sileſians*, with the modern *Italians*, and *Chineſe*, begin it at Sun-ſetting: and the antient *Babylonians*, *Perſians*, *Syrians*, with the modern *Greeks*, at Sun-riſing.

Hours. 381. An *Hour* is a certain determinate part of the Day, and is either equal or unequal. An equal Hour is the 24th part of a mean natural Day, as ſhewn

ſhewn by well-regulated Clocks and Watches; but theſe Hours are not quite equal as meaſured by the returns of the Sun to the Meridian, becauſe of the obliquity of the Ecliptic and Sun's unequal motion in it, § 224—245. Unequal Hours are thoſe by which the Artificial Day is divided into twelve Parts, and the Night into as many.

382. An Hour is divided into 60 equal parts called *Minutes*, a Minute into 60 equal parts called *Seconds*, and theſe again into 60 equal parts called *Thirds*. The *Jews*, *Chaldeans*, and *Arabians*, divide the Hour into 1080 equal parts called *Scruples*; which number contains 18 times 60, ſo that one minute contains 18 Scruples. Minutes, Seconds, Thirds, and Scruples.

383. A *Cycle* is a perpetual round, or circulation of the ſame parts of time of any ſort. The *Cycle of the Sun* is a revolution of 28 years, in which time the days of the months return again to the ſame days of the week; the Sun's Place to the ſame Signs and Degrees of the Ecliptic on the ſame months and days, ſo as not to differ one degree in 100 years; and the Leap-years begin the ſame courſe over again with reſpect to the days of the week on which the days of the months fall. The *Cycle of the Moon*, commonly called the *Golden Number*, is a revolution of 19 years; in which time, the Conjunctions, Oppoſitions and other Aſpects of the Moon, are within an hour and half of being the ſame as they were on the ſame days of the months 19 years before. The *Indiction* is a revolution of 15 years, uſed only by the *Romans* for indicating the times of certain payments made by the ſubjects to the Republic: It was eſtabliſhed by *Conſtantine*, A. D. 312. Cycles of the Sun, Moon, and Indiction.

384. The year of our SAVIOUR's Birth, according to the vulgar Æra, was the 9th year of the Solar Cycle; the firſt year of the Lunar Cycle; and the 312th year after his birth was the firſt year of the *Roman* Indiction. Therefore, to find the year of the Solar Cycle, add 9 to any given year To find the Years of theſe Cycles.

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of CHRIST, and divide the ſum by 28, the Quotient is the number of Cycles elapſed ſince his birth, and the remainder is the Cycle for the given year: if nothing remains, the Cycle is 28. To find the Lunar Cycle, add 1 to the given year of CHRIST, and divide the ſum by 19; the Quotient is the number of Cycles elapſed in the interval, and the remainder is the Cycle for the given year: if nothing remains, the Cycle is 19. Laſtly, ſubtract 312 from the given year of CHRIST, and divide the remainder by 15; and what remains after this diviſion is the Indiction for the given year: if nothing remains, the Indiction is 15.

The deficiency of the Lunar Cycle, and conſequence thereof.

385. Although the above deficiency in the Lunar Circle of an hour and half every 19 years be but ſmall, yet in time it becomes ſo ſenſible as to make a whole Natural Day in 310 years. So that, although this Cycle be of uſe, when the Golden Numbers are rightly placed againſt the days of the months in the Calendar, as in our *Common Prayer Books*, for finding the days of the mean Conjunctions or Oppoſitions of the Sun and Moon, and conſequently the time of *Eaſter*; it will only ſerve for 310 years, *Old Stile*. For as the New and Full Moons anticipate a day in that time, the Golden Numbers ought to be placed one day earlier in the Calendar for the next 310 years to come. Theſe Numbers were rightly placed againſt the days of New Moon in the Calendar, by the Council of *Nice*, A. D. 325; but the anticipation, which has been neglected ever ſince, is now grown almoſt into 5 days; and therefore all the Golden Numbers ought now to be placed 5 days higher in the Calendar for the *Old Stile* than they were at the time of the ſaid Council; or ſix days lower for the *New Stile*, becauſe at preſent it differs 11 days from the *Old*.

How to find the day of the New Moon by the Golden Number.

386. In the annexed Table, the Golden Numbers under the months ſtand againſt the days of New Moon in the left-hand column, for the *New Stile*;

Days	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octob.	Nov.	Dec.
1	9		9	17	17	6				11		19
2		17			6	14	14	3	11		19	
3	17	6	17	6			3	11		19	8	8
4	6		6	14	14	3			19	8		16
5		14			3	11	11	19	8		16	
6	14	3	14	3			19			16	5	5
7	3		3	11	11	19		8	16			13
8		11			19	8	8	16	5	5	13	
9	11	19	11	19						13		2
10			19	8	8	16	16	5	13		2	10
11	19	8					5	13	2	2	10	
12	8	16	8	16	16	5				10		18
13					5	13	13	2	10		18	7
14	16	5	16	5			2	10	18	18	7	
15	5		5	13	13	2				7		15
16		13			2	10	10	18	7		15	
17	13	2	13	2			18	7		15	4	4
18	2		2	10	10	18			15			12
19		10			18	7	7	15	4	4	12	
20	10	18	10	18			15			12	1	1
21	18		18	7	7	15		4	12			9
22		7			15	4	4	12	1	1	9	
23	7	15	7	15			12			9	17	17
24			15	4	4	12		1	9			6
25	15	4			12		1	9	17	17	6	
26	4		4	12		1				6		14
27		12		1	1	9	9	17	6		14	
28	12	1	12		9		17	6	14	14	3	3
29	1		1	9		17				3		11
30					17	6	6	14	3		11	
31	9		0				14	3		11		19

Stile; adapted chiefly to the second year after Leap-year, as being the nearest mean for all the four; and will serve till the year 1900. Therefore, to find the day of New Moon in any month of a given year till that time, look for the Golden Number of that year under the desired month, and against it, you have the day of New Moon in the left-hand column. Thus, suppose it were required to find the day of New Moon in *September* 1757; the Golden Number for that year is 10, which I look for under *September*, and right against it in the left-hand column I find 13, which is the day of New Moon in that month. *N. B.* If all the Golden Numbers, except 17 and 6, were set one day lower in the Table, it would serve from the beginning of the year 1900 till the End of the year 2199. The first Table after this Chapter shews the Golden Number for 4000 years after the birth of CHRIST; by looking for the even hundreds of any given year at the left hand, and for the rest to make up that year at the head of the Table; and where the columns meet, you have the Golden Number (which is the same both in *Old* and *New Stile)* for the given year. Thus, suppose the Golden Number was wanted for the year 1757; I look for 1700 at the left hand of the Table, and for 57 at the top of it; then guiding my eye downward from 57 to over-against 1700, I find 10, which is the Golden Number for that year.

387. But because the Lunar Cycle of 19 years sometimes includes five Leap-years, and at other times only four, this Table will sometimes vary a day from the truth in Leap-years after *February*. And it is impossible to have one more correct, unless we extend it to four times 19 or 76 years; in which there are 19 Leap-years without a remainder. But even then to have it of perpetual use, it must be adapted to the *Old Stile*; because in every centurial year not divisible by 4, the regular course of Leap-years is interrupted in the *New*; as will be

A perpetual Table of the time of New Moon to the nearest hour, for the *Old Stile*.

be the cafe in the year 1800. Therefore, upon the regular *Old Stile* plan, I have computed the following Table of the mean times of all the New Moons to the neareft hour for 76 years; beginning with the year of CHRIST 1724, and ending with the year 1800.

This Table may be made perpetual, by deducting 6 hours from the time of New Moon in any given year and month from 1724 to 1800, in order to have the mean time of New Moon in any year and month 76 years afterward; or deducting 12 hours for 152 years, 18 hours for 228 years; and 24 hours for 304 years; becaufe in that time the changes of the Moon anticipate almoft a complete natural day. And if the like number of hours be added for fo many years paft, we fhall have the mean time of any New Moon already elapfed. Suppofe, for example, the mean time of Change was required for *January* 1802; deduct 76 years, and there remains 1726, againft which in the following Table, under *January*, I find the time of New Moon was on the 21ft day, at 11 in the evening: from which take 6 hours, and there remains the 21ft day, at 5 in the evening, for the mean time of Change in *January* 1802. Or, if the time be required for *May*, A. D. 1701, add 76 years, and it makes 1777, which I look for in the Table, and againft it under *May* I find the New Moon in that year falls on the 25th day, at 9 in the evening; to which add 6 hours, and it gives the 26th day, at 3 in the Morning, for the time of New Moon in *May*, A. D. 1701. By this addition for time paft, or fubtraction for time to come, the Table will not vary 24 hours from the truth in lefs than 14592 years. And if, inftead of 6 hours for every 76 years, we add or fubtract only 5 hours 52 minutes, it will not vary a day in 10 millions of years.

Although this Table is calculated for 76 years only, and according to the *Old Stile*, yet by means of two easy Equations it may be made to answer as exactly to the *New Stile*, for any time to come. Thus, because the year 1724 in this Table is the first year of the Cycle for which it is made; if from any year of CHRIST after 1800 you subtract 1723, and divide the overplus by 76, the quotient will shew how many entire Cycles of 76 years are elapsed since the beginning of the Cycle here provided for; and the remainder will shew the year of the current Cycle answering to the given year of CHRIST. Hence, if the remainder be 0, you must instead thereof put 76, and lessen the Quotient by unity.

Then, look in the left-hand column of the Table for the number in your remainder, and against it you will find the times of all the mean New Moons in that year of the present Cycle. And whereas in 76 *Julian* years the Moon anticipates 5 hours 52 minutes, if therefore these 5 hours 52 minutes be multiplied by the above-found Quotient; that is, by the number of entire Cycles past; the product subtracted from the times in the Table will leave the corrected times of the New Moons to the *Old Stile*; which may be reduced to the *New Stile* thus:

Divide the number of entire hundreds in the given year of CHRIST by 4, multiply this quotient by 3, to the product add the remainder, and from their sum subtract 2: this last remainder denotes the number of days to be added to the times above corrected, in order to reduce them to the *New Stile*. The reason of this is, that every 400 years of the *New Stile* gains 3 days upon the *Old Stile*: one of which it gains in each of the centurial years succeeding that which is exactly divisible by 4 without a remainder; but then, when you have found the days so gained, 2 must be subtracted from their number on account of the rectifications made in the Calendar by the Council of *Nice*, and since by

Pope

Pope *Gregory*. It muſt alſo be obſerved, that the additional days found as above directed, do not take place in the centurial Years which are not multiples of 4 till *February* 29th, *Old Stile*, for on that day begins the difference between the *Stiles*; till which day, therefore, thoſe that were added in the preceding years muſt be uſed. The following Example will make this accommodation plain.

Required the mean time of New Moon in June, A. D. 1909, *N. S.*

From 1909 take 1723 years, and there remains	186
Which divided by 76, gives the quotient 2 and the remainder —	34
Then, againſt 34 in the Table is *June* — —	5^{d} 8^{h} 0^{m} Afternoon.
And 5^{h} 52^{m} multiplied by 2 make to be ſubtr. —	11 44
Remains the mean time according to the *Old Stile*, *June* — — —	5^{d} 9^{h} 16^{m}
Entire hundreds in 1909 are 19, which divide by 4, quotes — — —	4
And leaves a remainder of	3
Which quotient multiplied by 3 makes 12, and the remainder added makes — — — —	15
From which ſubtract 2, and there remains —	13
Which number of days added to the above time, *Old Stile*, gives *June* —	18^{d} 9^{h} 16^{m} Morn. *N. S.*

So the mean time of New Moon in *June* 1909 *New Stile* is the 18th day, at 16 minutes past 9 in the Morning.

If 11 days be added to the time of any New Moon in this Table, it will give the time thereof according to the *New Stile* till the year 1800. And if 14 days 18 hours 22 minutes be added to the mean time of New Moon in either *Stile*, it will give the mean time of the next Full Moon according to that *Stile*.

A Table

A TABLE *shewing the times of all the mean Changes of the Moon, to the nearest Hour, through four Lunar Periods, or 76 years.* M *signifies morning,* A *afternoon.*

Years of the Cyc.	A.D.	January D.	January H.	February D.	February H.	March D.	March H.	April D.	April H.
1	1724	14	5 A	13	5M	13	6 A	12	7M
2	1725	3	2M	1	2 A	3	3M	1	4 A
3	1726	21	11 A	20	11M	21	12 A	20	1 A
4	1727	11	8M	9	9 A	11	9M	9	10 A
5	1728	30	6M	28	7 A	29	7M	27	8 A
6	1729	18	2 A	17	3M	18	4 A	17	4M
7	1730	7	11 A	6	0 A	8	1M	6	1 A
8	1731	26	9 A	25	10M	26	10 A	25	11M
9	1732	16	5M	14	6 A	15	7M	13	8 A
10	1733	4	2 A	3	3M	4	4 A	3	4M
11	1734	23	0 A	22	1M	23	1 A	22	2M
12	1735	12	9 A	11	9M	12	10 A	11	11M
13	1736	2 31	5M 6 A		——	1 30	7M 8 A	29	9M
14	1737	20	3M	18	4 A	20	4M	18	5 A
15	1738	9	11M	7	12 A	9	1 A	8	1M
16	1739	28	9M	26	10 A	28	11M	26	12 A
17	1740	17	6 A	16	7M	16	8 A	15	9M
18	1741	6	3M	4	4 A	6	4M	4	5 A
19	1742	24	12 A	23	1 A	25	2M	23	3 A
20	1743	14	9M	12	10 A	14	11M	12	12 A
21	1744	3	6 A	2	7M	2	8 A	1 30	9M 9 A
22	1745	21	4 A	20	5M	21	5 A	20	6M
23	1746	10	12 A	9	1 A	11	2M	9	3 A
24	1747	29	10 A	28	11M	29	11 A	28	0 A
25	1748	19	6M	17	7 A	18	8M	16	9 A
26	1749	7	3 A	6	4M	7	5 A	6	6M

A TABLE *of the mean New Moons, &c.*

Lunar Cyc.	A.D.	*May* D.	*May* H.	*June* D.	*June* H.	*July* D.	*July* H.	*August* D.	*August* H.
1	1724	11	8 A	0	8M	9	9 A	8	10M
2	1725	1 30	4M 5 A	29	6M	28	7 A	27	8M
3	1726	20	1M	18	2 A	18	3M	16	4 A
4	1727	9	11M	7	12 A	7	0 A	6	1M
5	1728	27	8M	25	9 A	25	10M	23	11 A
6	1729	16	5 A	15	6M	14	7 A	12	7M
7	1730	6	2M	4	3 A	4	3M	2	4 A
8	1731	24	11 A	23	0 A	23	1M	21	2 A
9	1732	13	8M	11	9 A	11	10M	9	11 A
10	1733	2	5 A	1 30	6M 7 A	30	8M	28	8 A
11	1734	21	2 A	20	3M	19	4 A	18	5M
12	1735	10	11 A	9	0 A	9	1M	7	2 A
13	1736	28	9 A	27	10M	26	11 A	25	0 A
14	1737	18	5M	16	6 A	16	7M	14	8 A
15	1738	7	2 A	6	3 A	5	4 A	4	5M
16	1739	26	0 A	25	1M	24	2 A	23	3M
17	1740	14	9 A	13	10M	12	11 A	11	0 A
18	1741	4	5M	2	6 A	2 31	7M 7 A	30	8M
19	1742	23	3M	21	4 A	21	5M	19	6 A
20	1743	12	0 A	11	1M	10	2 A	9	3M
21	1744	30	10M	28	11 A	28	0 A	26	12 A
22	1745	19	6 A	18	7M	17	8 A	16	8M
23	1746	9	3M	7	4 A	7	5M	5	6 A
24	1747	27	12 A	26	1 A	26	2M	24	3 A
25	1748	16	9M	14	10 A	14	11M	12	12 A
2	1749	5	6 A	4	7M	3	8 A	2 31	9M 9 A

A TABLE *of the mean New Moons, &c.*

Yrs of the Cyc.	A.D.	*September* D.	H.	*October* D.	H.	*November* D.	H.	*December* D.	H.
1	1724	6	10 A	6	11M	4	12 A	4	1 A
2	1725	25	8 A	25	9M	23	10 A	23	11M
3	1726	15	5M	14	5 A	13	6M	12	7 A
4	1727	4	1 A	4	2M	2	3 A	2 31	4M 5 A
5	1728	22	11M	21	12 A	20	1 A	20	2M
6	1729	11	8 A	11	9M	9	10 A	9	11M
7	1730	2 30	5M 6 A	30	7M	28	8 A	28	9M
8	1731	20	2M	19	3 A	18	4M	17	5 A
9	1732	8	11M	7	12 A	6	1 A	6	2M
10	1733	27	9M	26	10 A	25	11M	24	11 A
11	1734	16	5 A	16	6M	14	7 A	14	8M
12	1735	6	2M	5	3 A	4	4M	3	5 A
13	1736	23	12 A	23	1 A	22	2M	21	3 A
14	1737	13	8M	12	9 A	11	10M	10	11 A
15	1738	2	5 A	2 31	6M 7 A	30	8M	29	8 A
16	1739	21	3 A	21	4M	19	5 A	19	6M
17	1740	9	12 A	9	1 A	8	2M	7	3 A
18	1741	28	9 A	28	10M	26	11 A	26	11M
19	1742	18	6M	17	7 A	16	8M	15	9 A
20	1743	7	3 A	7	4M	5	5 A	5	6M
21	1744	25	1 A	25	2M	23	3 A	23	3M
22	1745	14	9 A	14	10M	12	11 A	12	0 A
23	1746	4	6M	3	7 A	2	8M	1 31	9 A 10M
24	1747	23	3M	22	4 A	21	5M	20	6 A
25	1748	11	0 A	11	1M	9	2 A	9	3M
26	1749	30	10M	29	11 A	28	0 A	27	12 A

Yrs of the Cyc.	A.D.	January D.	January H.	February D.	February H.	March D.	March H.	April D.	April H.
27	1750	26	1 A	25	2M	26	3 A	25	4M
28	1751	15	10 A	14	11M	15	11 A	14	0 A
29	1752	5	6M	3	7 A	4	8M	2	9 A
30	1753	23	4M	21	5 A	23	6M	21	7 A
31	1754	12	1 A	11	2M	12	3 A	11	4M
32	1755	1 31	10 A 11M	—		1 31	11 A 0 A	29	12 A
33	1756	20	7 A	19	8M	19	9 A	18	9M
34	1757	9	4M	7	5 A	9	6M	7	7 A
35	1758	28	2M	26	3 A	28	3M	26	4 A
36	1759	17	10M	15	11 A	17	0 A	16	1M
37	1760	6	7 A	5	8M	5	9 A	4	10M
38	1761	24	5 A	23	6M	24	7 A	23	8M
39	1762	14	2M	12	3 A	14	3M	12	4 A
40	1763	3	11M	1	12 A	3	0 A	2	1M
41	1764	22	8M	20	9 A	21	10M	19	11 A
42	1765	10	5 A	9	6M	10	6 A	9	7M
43	1766	29	2 A	28	3M	29	4 A	28	5M
44	1767	18	11 A	17	0 A	19	1M	17	2 A
45	1768	8	8M	6	9 A	7	10M	5	11 A
46	1769	26	6M	24	7 A	26	7M	24	8 A
47	1770	15	2 A	14	3M	15	4 A	14	5M
48	1771	4	11M	3	0 A	5	1M	3	2 A
49	1772	23	9 A	22	10M	22	10 A	21	11M
50	1773	12	5M	10	6 A	12	7M	10	8 A
51	1774	1 31	2 A 3M	—		1 31	4 A 5M	29	5 A
52	1775	20	0 A	19	1M	20	2 A	19	3M
53	1776	9	9 A	8	10M	8	10 A	7	11M

A TABLE of the mean New Moons continued.

A TABLE *of the mean new Moons continued.*

Yrs of the Cyc.	A.D.	*May* D.	H.	*June* D.	H.	*July* D.	H.	*August* D.	H.
27	1750	24	4 A	23	5M	22	6 A	21	7M
28	1751	13	12 A	12	1 A	12	2M	10	3 A
29	1752	2 31	9M 10 A	30	11M	29	12 A	28	0 A
30	1753	21	7M	19	8 A	19	9M	17	10 A
31	1754	10	4 A	9	5M	8	6 A	7	7M
32	1755	29	1 A	28	2M	27	3 A	25	3M
33	1756	17	10 A	16	11M	15	12 A	14	1 A
34	1757	7	7M	5	8 A	5	9M	3	10 A
35	1758	26	4M	24	5 A	24	6M	22	7 A
36	1759	15	1 A	14	2M	13	3 A	12	2 M
37	1760	3	10 A	2	11M	1 31	12 A 1 A	30	1M
38	1761	22	9 A	21	10M	20	10 A	19	11M
39	1762	12	4M	10	5 A	10	6M	8	7 A
40	1763	1 31	1 A 2M	29	3 A	29	4M	27	4 A
41	1764	19	11M	17	12 A	17	1 A	16	2M
42	1765	8	7 A	7	8M	6	9 A	5	10M
43	1766	27	5 A	26	6M	25	7 A	24	8M
44	1767	17	2M	15	3 A	15	4M	13	5 A
45	1768	5	11M	3	12 A	3	1 A	2 31	2M 2 A
46	1769	24	8M	22	9 A	22	10M	20	11 A
47	1770	13	5 A	12	4M	11	7 A	10	8M
48	1771	3	2M	1	3 A	1 30	4M 5 A	29	5M
49	1772	20	11 A	19	0 A	19	1M	17	2 A
50	1773	10	8M	8	9 A	8	9M	6	10 A
51	1774	29	6M	27	7 A	27	8M	25	8 A
52	1775	18	3 A	17	4M	16	5 A	15	6M
53	1776	6	12 A	5	0 A	5	1M	3	2 A

A TABLE *of the mean New Moons continued.*

Yrs of th C.c.	A.D.	*September* D.	H.	*October* D.	H.	*November* D.	H	*December* D.	H.
27	1750	19	7 A	19	8M	17	9 A	17	10M
28	1751	9	3M	8	4 A	7	5M	6	6 A
29	1752	27	1M	26	2 A	25	3M	24	3 A
30	1753	16	10M	15	11 A	14	0 A	14	1M
31	1754	5	7 A	5	8M	3	9 A	3	10M
32	1755	24	4 A	24	5M	22	6 A	22	6M
33	1756	13	1M	12	2 A	11	3M	10	4 A
34	1757	2	10M	1 31	11 A 0 A	30	1M	29	1 A
35	1758	21	7M	20	8 A	19	9M	18	10 A
36	1759	10	4 A	10	5M	8	6 A	8	7M
37	1760	28	2 A	28	3M	26	4 A	26	4M
38	1761	17	11 A	17	0 A	16	1M	15	2 A
39	1762	7	7M	6	8 A	5	9M	4	10 A
40	1763	26	5M	25	6 A	24	7M	23	7 A
41	1764	14	2 A	14	3M	12	4 A	12	5M
42	1765	3	10 A	3	11M	1	12 A	1 31	1 A 1M
43	1766	22	8 A	22	9M	20	10 A	20	11M
44	1767	12	6M	11	6 A	10	7M	9	8 A
45	1768	30	3M	29	4 A	28	5M	27	5 A
46	1769	19	11M	18	12 A	17	1 A	17	2M
47	1770	8	8 A	8	9M	6	10 A	6	11M
48	1771	27	6 A	27	7M	25	8 A	25	9M
49	1772	16	2M	15	3 A	14	4M	13	5 A
50	1773	5	11M	4	12 A	3	1 A	3	2M
51	1774	24	9M	23	10 A	22	11M	21	11 A
52	1775	13	6 A	13	7M	11	8 A	11	9M
53	1776	2	2M	1 31	3 A 4M	29	5 A	29	5M

A TABLE *of the mean New Moons concluded.*

Yrs of the Cyc.	A.D.	*January* D.	H	*February* D.	H.	*March* D.	H.	*April* D.	H.
54	1777	27	6 A	26	7 M	27	8 A	26	9 M
55	1778	17	3 M	15	4 A	17	5 M	15	6 A
56	1779	6	0 A	5	1 M	6	2 A	5	3 M
57	1780	25	10 M	23	11 A	24	11 M	22	12 A
58	1781	13	6 A	12	7 M	13	8 A	12	9 M
59	1782	3	3 M	1	4 A	3	5 M	1	6 A
60	1783	22	1 M	20	2 A	22	2 M	20	3 A
61	1784	11	9 M	9	10 A	10	11 M	8	12 A
62	1785	29	7 M	27	8 A	29	9 M	27	10 A
63	1786	18	4 A	17	5 M	18	5 A	17	6 M
64	1787	7	12 A	6	1 A	8	2 M	6	3 A
65	1788	26	10 A	25	11 M	25	12 A	24	1 A
66	1789	15	7 M	13	8 A	15	9 M	13	10 A
67	1790	4	4 A	3	5 M	4	5 A	3	6 M
68	1791	23	1 A	22	2 M	23	3 A	22	4 M
69	1792	12	10 A	11	11 M	11	12 A	10	1 A
70	1793	1 30	7 M 8 A	——		1 30	9 M 10 A	29	10 M
71	1794	20	5 M	18	6 A	20	6 M	18	7 A
72	1795	9	1 A	8	2 M	9	3 A	8	4 M
73	1796	28	11 M	26	12 A	27	0 A	26	1 M
74	1797	16	7 A	15	8 M	16	9 A	15	10 M
75	1798	6	4 M	4	5 A	6	6 M	4	7 A
76	1799	25	2 M	23	3 A	25	4 M	23	5 A
1	1800	14	11 M	12	12 A	13	0 A	12	1 M

The year 1800 begins a new Cycle.

A TABLE *of the mean New Moons concluded.*

Yrs of the Cyc.	A.D.	*May* D.	H.	*June* D.	H.	*July* D.	H.	*August* D.	H.
54	1777	25	9 A	24	10M	23	11 A	22	0 A
55	1778	15	6M	13	7 A	13	8M	11	9 A
56	1779	4	3 A	3	4M	2	5 A	1 30	6M 6 A
57	1780	22	0 A	21	1M	20	2 A	19	3M
58	1781	11	9 A	10	10M	9	11 A	8	0 A
59	1782	1 30	6M 7 A	29	8M	28	9 A	27	9M
60	1783	20	3M	18	4 A	18	5M	16	6 A
61	1784	8	0 A	7	1M	6	2 A	5	3M
62	1785	27	10M	25	11 A	25	0 A	24	1M
63	1786	16	6 A	15	7M	14	8 A	13	9M
64	1787	6	3M	4	4 A	4	5M	2	6 A
65	1788	24	1M	22	2 A	22	3M	20	4 A
66	1789	13	10M	11	11 A	11	0 A	10	1M
67	1790	2	6 A	1 30	7M 8 A	30	9M	28	9 A
68	1791	21	4 A	20	5M	19	6 A	18	7M
69	1792	10	1M	8	2 A	8	3M	6	4 A
70	1793	28	11 A	27	0 A	27	1M	25	1 A
71	1794	18	7M	16	8 A	16	9M	14	10 A
72	1795	7	4 A	6	5M	5	6 A	4	7M
73	1796	25	1 A	24	2M	23	3 A	22	4M
74	1797	14	10 A	13	11M	12	12 A	11	1 A
75	1798	4	7M	2	8 A	2 31	9M 10 A	30	10M
76	1799	23	5M	21	6 A	21	6M	19	8 A
1	1800	11	1 A	10	2M	9	3 A	8	4M

A Table of the mean New Moons concluded.

Yrs of the Cyc.	A.D.	September D.	September H.	October D.	October H.	November D.	November H.	December D.	December H.
54	1777	20	12 A	20	1 A	19	2 M	18	3 A
55	1778	10	9 M	9	10 A	8	11 M	7	12 A
56	1779	29	7 M	28	8 A	27	9 M	26	9 A
57	1780	17	3 A	17	4 M	15	5 A	15	6 M
58	1781	6	12 A	6	1 A	5	2 M	4	3 A
59	1782	25	10 A	25	11 M	23	12 A	23	0 A
60	1783	15	6 M	14	7 A	13	8 M	12	9 A
61	1784	3	3 A	3	4 M	1	5 A	1 30	6 M 6 A
62	1785	22	1 A	22	2 M	20	3 A	20	3 M
63	1786	11	9 A	11	10 M	9	11 A	9	0 A
64	1787	1 30	6 M 7 A	30	8 M	28	9 A	28	9 M
65	1788	19	4 M	18	5 A	17	6 M	16	7 A
66	1789	8	1 A	8	2 M	6	3 A	6	4 M
67	1790	27	10 M	26	11 A	25	0 A	24	12 A
68	1791	16	7 A	16	8 M	14	9 A	14	10 M
69	1792	5	4 A	4	5 A	3	6 M	2	7 A
70	1793	24	2 M	23	3 A	22	4 M	21	4 A
71	1794	13	10 M	12	11 A	11	0 A	11	1 M
72	1795	2	7 A	2 31	8 M 9 A	30	10 M	29	10 A
73	1796	20	4 A	20	5 M	18	6 A	18	7 M
74	1797	10	1 M	9	2 A	8	3 M	7	4 A
75	1798	28	11 A	28	0 A	27	1 M	26	1 A
76	1799	18	8 M	17	9 A	16	10 M	15	11 A
1	1800	6	4 A	6	5 M	4	6 A	4	7 M

Easter Cycle deficient. 388. The *Cycle of Easter*, alſo called the *Dionyſian Period*, is a revolution of 532 years, found by multiplying the Solar Cycle 28 by the Lunar Cycle 19. If the New Moons did not anticipate upon this Cycle, *Easter-Day* would always be the *Sunday* next after the firſt Full Moon which follows the 21ſt of *March*. But, on account of the above anticipation, § 422. to which no proper regard was had before the late alteration of the *Stile*, the *Eccleſiaſtic Easter* has ſeveral times been a week different from the *true Easter* within this laſt Century: which inconvenience is now remedied by making the Table which uſed to find Eaſter *for ever*, in the Common Prayer Book, of no longer uſe than the Lunar difference from the *New Stile* will admit of.

389. The *earlieſt Eaſter poſſible* is the 22d of *March*, the *lateſt* the 25th of *April*. Within theſe limits are 35 days, and the number belonging to each of them is called the *Number of Direction*; becauſe thereby the time of Eaſter is found for any given year. *Number of Direction.* To find the Number of Direction, according to the *New Stile*, enter Table V. following this Chapter, with the compleat hundreds of any given year at the top, and the years thereof (if any) below an hundred at the left hand; and where the columns meet is the Dominical Letter for the given year. Then, enter Table I. with the compleat hundreds of the ſame year at the left hand, and the years below an hundred at the top; and where the columns meet is the Golden Number for the ſame year. Laſtly, enter Table II. with the Dominical Letter at the left hand and Golden Number at the top; and where the columns meet is the Number of Direction for that year; which number, added to the 21ſt day of *March*, ſhews on what day either of *March* or *April Eaſter-Sunday* falls in that year. Thus, the Dominical Letter *New Stile* for the year 1757 is *B* (Table V) and the Golden Number is 10, (Table I) by which

in Table II. the Number of Direction is found to be 20; which, reckoning from the 21ſt of *March*, ends on the 10th of *April*, that *that* is *Eaſter-Sunday* in the year 1757. *N. B.* There are always two Dominical Letters to the Leap-year, the firſt of which takes place to the 24th of *February*, the laſt for the following part of the year. To find the true *Eaſter*.

390. *The firſt ſeven Letters of the Alphabet* are commonly placed in the annual Almanacks, to ſhew on what days of the week the days of the months fall throughout the year. And becauſe one of thoſe ſeven Letters muſt neceſſarily ſtand againſt *Sunday*, it is printed in a capital form, and called the *Dominical Letter:* the other ſix being inſerted in ſmall characters, to denote the other ſix days of the week. Now, ſince a common *Julian Year* contains 365 Days, if this number be divided by 7 (the number of days in a week) there will remain one day. If there had been no remainder, it is plain the year would conſtantly begin on the ſame day of the week. But ſince 1 remains, it is as plain that the year muſt begin and end on the ſame day of the week; and therefore the next year will begin on the day following. Hence, when *January* begins on *Sunday*, *A* is the Dominical or *Sunday* Letter for that year: then, becauſe the next year begins on *Monday*, the *Sunday* will fall on the ſeventh day, to which is annexed the ſeventh Letter *G*, which therefore will be the Dominical Letter for all that year: and as the third year will begin on *Tueſday*, the *Sunday* will fall on the ſixth day; therefore *F* will be the *Sunday* Letter for that year. Whence it is evident, that the *Sunday* Letters will go annually in a retrograde order thus, *G*, *F*, *E*, *D*, *C*, *B*, *A*. And in the courſe of ſeven years, if they were all common ones, the ſame days of the week and Dominical Letters would return to the ſame days of the months. But becauſe there are 366 days in a Leap-year, if this number be divided by 7, there will remain two days over and above the Dominical Letter.

52 weeks of which the year consists. And therefore, if the Leap-year begins on *Sunday*, it will end on *Monday*; and the next year will begin on *Tuesday*, the first *Sunday* whereof must fall on the sixth of *January*, to which is annexed the Letter *F*, and not *G*, as in common years. By this means, the Leap-year returning every fourth year, the order of the Dominical Letters is interrupted; and the Series cannot return to its first state till after four times seven, or 28 years; and then the same days of the months return in order to the same days of the week as before.

To find the Dominical Letter.

391. *To find the Dominical Letter for any year either before or after the Christian Æra.* In Table III. or IV. for *Old Stile*, or V. for *New Stile*, look for the hundreds of years at the head of the Table, and for the years below an hundred (to make up the given year) at the left hand: and where the columns meet, you have the Dominical Letter for the year desired. Thus, suppose the Dominical Letter be required for the year of CHRIST 1758, *New Stile*, I look for 1700 at the head of Table V. and for 58 at the left hand of the same Table; and in the angle of meeting, I find *A*, which is the Dominical Letter for that year. If it was wanted for the same year *Old Stile*, it would be found by Table IV. to be *D*. But *to find the Dominical Letter for any given year before* CHRIST, subtract one from *that* year, and then proceed in all respects as just now taught, to find it by Table III. Thus, suppose the Dominical Letter be required for the 585th year before the first year of CHRIST, look for 500 at the head of Table III. and for 84 at the left hand; in the meeting of these columns is *FE*, which were the Dominical Letters for that year, and shews that it was a Leap-year; because Leap-year has always two Dominical Letters.

To find the Days of the Months.

392. *To find the day of the month answering to any day of the week, or the day of the week answering to any day of the month, for any year past or to come.* Having

Having found the Dominical Letter for the given year, enter Table VI. with the Dominical Letter at the head; and under it, all the days in that column are *Sundays*, in the divisions of the months; the next column to the right hand are *Mondays*; the next, *Tuesdays*; and so on to the last column under *G*; from which go back to the column under *A*, and thence proceed towards the right hand as before. Thus, in the year 1757, the Dominical Letter *New Stile* is *B*, in Table V; then in Table VI. all the days under *B* are *Sundays* in that year, *viz.* the 2d, 9th, 16th, 23d, and 30th of *January* and *October*; the 6th, 13th, 20th, and 27th of *February*, *March* and *November*; the 3d, 10th, and 17th of *April* and *July*, together with the 31st of *July*; and so on to the foot of the column. Then, of course, all the days under *C* on *Mondays*, namely, the 3d, 10th, *&c.* of *January* and *October*; and so of all the rest in that column. If *the day of the week answering to any day of the month* be required, it is easily had from the same Table by the Letter that stands at the top of the column in which the given day of the month is found. Thus, the Letter that stands over the 28th of *May* is *A*; and in the year 585 before CHRIST, the Dominical Letters were found to be *FE*, § 391; which being a Leap-year, and *E* taking place from the 24th of *February* to the end of that year, shews by the Table that the 25th of *May* was on a *Sunday*; and therefore the 28th must have been on a *Wednesday*; for when *E* stands for *Sunday*, *F* must stand for *Monday*, *G* for *Tuesday*, &c. Hence, as it is said that the famous Eclipse of the Sun foretold by THALES, by which a peace was brought about between the *Medes* and *Lydians*, happened on the 28th of *May*, in the 585th year before CHRIST, it fell on a *Wednesday*.

393. From the multiplication of the Solar Cycle of 28 years into the Lunar Cycle of 19 years, and the *Roman* Indiction of 15 years, arises the great *Julian Period.*

Julian Period, consisting of 7980 years, which had its beginning 764 years before *Strauchius*' supposed year of the Creation (for no later could all the three Cycles begin together) and it is not yet compleated: and therefore it includes all other Cycles, Periods, and Æras. There is but one year in the whole Period that has the same numbers for the three Cycles of which it is made up: and therefore, if historians had remarked in their writings the Cycles of each year, there had been no dispute about the time of any action recorded by them.

To find the year of this Period.

394. The *Dionysian* or vulgar Æra of CHRIST's birth was about the end of the year of the *Julian* Period 4713; and consequently the first year of his age, according to that account, was the 4714th year of the said Period. Therefore, if to the current year of CHRIST we add 4713, the sum will be the year of the *Julian* Period. So the year 1757 will be found to be the 6470th year of that Period. Or, to find the year of the *Julian* Period answering to any given year before the first year of CHRIST, subtract the number of that given year from 4714, and the remainder will be the year of the *Julian* Period. Thus, the year 585 before the first year of CHRIST (which was the 584th before his birth) was the 4129th year of the said Period. Lastly, to find the Cycles of the Sun, Moon, and Indiction for any given year of this Period, divide the given year by 28, 19, and 15; the three remainders will be the Cycles sought, and the Quotients the numbers of Cycles run since the beginning of the Period. So in the above 4714th year of the *Julian* Period, the Cycle of the Sun was 10, the Cycle of the Moon 2, and the Cycle of Indiction 4; the Solar Cycle having run through 168 courses, the Lunar 248, and the Indiction 314.

And the Cycles of that year.

The true Æra of CHRIST's birth.

395. The vulgar Æra of CHRIST's birth was never settled till the year 527, when *Dionysius Exiguus*, a *Roman* Abbot, fixed it to the end of the 4713th year of the *Julian* Period, which was four years

years too late.—For our SAVIOUR was born before the Death of *Herod*, who ſought to kill him as ſoon as he heard of his birth. And according to the teſtimony of *Joſephus* (B. xvii. ch. 8.) there was an Eclipſe of the Moon in the time of *Herod*'s laſt illneſs; which Eclipſe appears by our Aſtronomical Tables to have been in the year of the *Julian* Period 4710, *March* 13th, at 3 hours paſt midnight, at *Jeruſalem*. Now as our SAVIOUR muſt have been born ſome months before *Herod*'s Death, ſince in the interval he was carried into *Egypt*, the lateſt time in which we can fix the true Æra of his Birth is about the end of the 4709th year of the *Julian* Period.

There is a remarkable Prophecy delivered to us in the ninth chapter of the book of *Daniel*, which, from a certain *Epoch*, fixes the time of reſtoring the State of the *Jews*, and of building the Walls of *Jeruſalem*, the Coming of the MESSIAH, his Death, and the Deſtruction of *Jeruſalem*.—But ſome parts of this Prophecy (*Ver.* 25.) are ſo injudiciouſly pointed in our *Engliſh* tranſlation of the *Bible*, that, if they be read according to thoſe ſtops of pointing, they are quite unintelligible.—But the learned Dr. *Prideaux*, by altering theſe ſtops, makes the ſenſe very plain: and as he ſeems to me to have explained the whole of it better than any other author I have read on the ſubject, I ſhall ſet down the whole of the Prophecy according as he has pointed it, to ſhew in what manner he has divided it into four different parts.

Ver. 24. *Seventy weeks are determined upon thy People, and upon thy holy City, to finiſh the Tranſgreſſion, and to make an end of Sins, and to make reconciliation for Iniquity, and to bring in everlaſting Righteouſneſs, and to ſeal up the Viſion and the Prophecy, and to anoint the moſt holy.* Ver. 25. *Know therefore and underſtand, that from the going forth of the Commandment to reſtore and build* Jeruſalem *unto the* MESSIAH *the Prince ſhall be ſeven weeks and three-*

ſcore and two weeks, the ſtreet ſhall be built again, and the wall even in troublous times. Ver. 26. *And after threeſcore and two weeks ſhall* MESSIAH *be cut off, but not for himſelf, and the people of the Prince, that ſhall come, ſhall deſtroy the City and Sanctuary, and the end thereof ſhall be with a Flood, and to the end of the War deſolations are determined.* Ver. 27. *And he ſhall confirm the Covenant with many for one week, and in the midſt* * *of the week he ſhall cauſe the ſacrifice and the oblation to ceaſe, and for the overſpreading of abominations he ſhall make it deſolate even until the Conſummation, and that determined ſhall be poured upon the deſolate.*

This Commandment was given to *Ezra* by *Artaxerxes Longimanus*, in the ſeventh year of that King's reign (*Ezra*, ch. vii. ver. 11—26.) *Ezra* began the work, which was afterward accompliſhed by *Nehemiah*; in which they met with great oppoſition and trouble from the *Samaritans* and others, during the firſt ſeven weeks, or 49 years.

From this accompliſhment till the time when CHRIST's meſſenger *John* the Baptiſt began to preach the Kingdom of the MESSIAH, 62 weeks, or 434 years.

From thence to the beginning of CHRIST's public miniſtry, half a week, or 3½ years.

And, from thence to the death of CHRIST, half a week, or 3½ years; in which half week he preached, and *confirmed the Covenant* of the Goſpel with many of the *Jews*.

In all, from the going forth of the Commandment till the Death of CHRIST, 70 weeks, or 490 years.

And, laſtly, in a very ſtriking manner, the Prophecy foretels what ſhould come to paſs after the expiration of the *ſeventy weeks*; namely, *the Deſtruction of the City and Sanctuary by the People of the Prince that was to come*; which were the *Roman*

* The Doctor ſays, that this ought to be rendered, *the half part of the week*, not *the midſt*.

Armies, under the command of *Titus* their Prince, who invaded *Jerufalem* as a torrent, with their idolatrous images, which were an abomination to the *Jews*, and under which they marched againft them, invaded their land, and befieged their holy City, and by a calamitous war brought fuch utter deftruction upon both, that the *Jews* have never been able to recover themfelves, even to this day

Now, both by the undoubted Canon of *Ptolemy*, and the famous *Æra* of *Nabonaffar*, the beginning of the feventh year of the reign of *Artaxerxes Longimanus* King of *Perfia* (who is called *Ahafuerus* in the book of *Efther*) is pinned down to the 4256th year of the *Julian* Period, in which year he gave *Ezra* the above mentioned ample Commiffion: from which count 490 years to the Death of CHRIST, and it will carry the fame to the 4746th year of the *Julian* Period.

Our *Saturday* is the *Jewifh* Sabbath: and it is plain, from St. *Mark*, ch. xv. ver. 42. and St. *Luke*, ch. xxiii. ver. 54. that CHRIST was crucified on a *Friday*, feeing the Crucifixion was on the day next before the *Jewifh* Sabbath.—And according to St. *John*, ch. xviii. ver. 28. on the day that the Paffover was to be eaten, at leaft by many of the *Jews*.

The *Jews* reckoned their months by the Moon, and their years by the revolution of the Sun: and they ate the Paffover on the 14th day of the month *Nifan*, which was the firft month of their year, reckoning from the firft appearance of the New Moon, which at that time of the year might be on the evening of the day next after the change, if the fky was clear. So that their 14th day of the month anfwers to our fifteenth day of the Moon, on which fhe is full.—Confequently, the Paffover was always kept on the day of Full Moon.

And the Full Moon at which it was kept, was *that* one which happened next after the Vernal Equinox.—For *Jofephus* exprefsly fays (*Antiq*. B. iii. ch. 10.) " The Paffover was kept on the 14th day " of "of the month *Nisan*, according to the Moon, "when the Sun was in *Aries*."—And the Sun always enters *Aries* at the instant of the Vernal Equinox; which, in our Saviour's time, fell on the 22d day of *March*.

The dispute among Chronologers about the year of CHRIST'S Death is limited to four or five years at most.—But, as we have shewn that he was crucified on the day of a Paschal Full Moon, and on a *Friday*, all that we have to do, in order to ascertain the year of his death, is only to compute in which of those years there was a Passover Full Moon on a *Friday*.—For, the Full Moons anticipate eleven days every year (12 Lunar Months being so much short of a Solar Year) and therefore, once in every three years at least, the *Jews* were obliged to set their Passover a whole month forwarder than it fell by the course of the Moon, on the year next before, in order to keep it at the Full Moon next after the Equinox; therefore there could not be two Passovers on the same day of the week within the compass of a few neighbouring years. And I find by calculation, the *only* Passover Full Moon that fell on a *Friday*, for several years before or after the disputed year of the Crucifixion, was on the third day of *April*, in the 4746th year of the *Julian* Period, which was the 490th year after *Ezra* received the above-mentioned Commission from *Artaxerxes Longimanus*, according to *Ptolemy*'s Canon, and the year in which the MESSIAH was to be cut off, according to the Prophecy, reckoning from the going forth of *that* Commission or Commandment: and this 490th year was the 33d year of our SAVIOUR'S Age, reckoning from the vulgar Æra of his birth; but the 37th, reckoning from the true Æra thereof.

And, when we reflect on what the *Jews* told him, some time before his death (*John* viii. 57.) "*Thou "art not yet fifty years old*," we must confess that it should seem much likelier to have been said to a

person

perſon near forty than to one but juſt turned of thirty. And we may eaſily ſuppoſe that St. *Luke* expreſſed himſelf only in round numbers, when he ſaid that *Chriſt was baptized about the 30th year of his age*, when he began his public miniſtry; as our SAVIOUR himſelf did, when he ſaid he ſhould lie *three days and three nights in the grave.*

The 4746th year of the *Julian* Period, which we have aſtronomically proved to be the year of the Crucifixion, was the 4th year of the 202d Olympiad; in which year, *Phlegon*, a heathen writer, tells us, *there was the moſt extraordinary Eclipſe of the Sun that ever was ſeen.* But I find by calculation, that there could be no total Eclipſe of the Sun at *Jeruſalem*, in a natural way, in that year.—So that what *Phlegon* here calls an Eclipſe of the Sun, ſeems to have been the great darkneſs for three hours at the time of our SAVIOUR's Crucifixion, as mentioned by the Evangeliſts: a darkneſs altogether ſupernatural, as the Moon was then in the ſide of the Heavens oppoſite to the Sun; and therefore could not poſſibly darken the Sun to any part of the Earth.

396. As there are certain fixed points in the Heavens from which Aſtronomers begin their computations, ſo there are certain points of time from which hiſtorians begin to reckon; and theſe points, or roots of time, are called *Æras* or *Epochs*. The moſt remarkable *Æras* are thoſe of the *Creation*, the *Greek Olympiads*, the Building of *Rome*, the *Æra* of *Nabonaſſar*, the Death of *Alexander*, the Birth of CHRIST, the *Arabian Hegira*, and the *Perſian Jeſdegird*: All which, together with ſeveral others of leſs note, have their Beginnings in the following Table fixed to the Years of the *Julian Period*, to the Age of the World at thoſe times, and to the Years before and after the year of CHRIST's birth.

A Table

A Table of remarkable Æras and Events.

	Julian Period.	Y. of the World	Before Christ.
1. The Creation of the World — — — —	706	0	4007
2. The Deluge, or *Noah*'s Flood — — — —	2362	1656	2351
3. The *Assyrian* Monarchy founded by *Nimrod* —	2537	1831	2176
4. The Birth of *Abraham* — — — — —	2714	2008	1999
5. The Destruction of *Sodom* and *Gomorrah* — —	2816	2110	1897
6. The Beginning of the Kingdom of *Athens* by *Cecrops*	3157	2451	1556
7. *Moses* receives the Ten Commandments — —	3222	2516	1491
8. The Entrance of the *Israelites* into *Canaan* — —	3262	2556	1451
9. The Destruction of *Troy* — — — — —	3529	2823	1184
10. The Beginning of King *David*'s Reign — —	3650	2944	1063
11. The Foundation of *Solomon*'s Temple — —	3701	2995	1012
12. The *Argonautic* Expedition — — — —	3776	3070	937
13. *Lycurgus* forms his excellent Laws — — —	3829	3103	884
14. *Arbaces*, the first King of the *Medes* — — —	3838	3132	875
15. *Mandaucus*, the second — — — — —	3865	3159	848
16. *Sosarmus*, the third — — — — — —	3915	3209	798
17. The Beginning of the *Olympiads* — — —	3938	3232	775
18. *Artica*, the fourth King of the *Medes* — —	3945	3239	768
19. The *Catonian Epocha* of the Building of *Rome* —	3961	3255	752
20. The Æra of *Nabonassar* — — — — —	3967	3261	746
21. The Destruction of *Samaria* by *Salmanesser* —	3992	3286	721
22. The first Eclipse of the Moon on Record — —	3993	3287	720
23. *Cardicea*, the fifth King of the *Medes* — —	3996	3290	717
24. *Phraortes*, the sixth — — — — — —	4058	3352	655
25. *Cyaxares*, the seventh — — — — —	4080	3374	633
26. The first *Babylonish* Captivity by *Nebuchadnezzar* -	4107	3401	606
27. The long War ended between the *Medes* and *Lydians*	4111	3405	602
28. The second *Babylonish* Captivity, and Birth of *Cyrus*	4114	3408	599
29. The Destruction of *Solomon*'s Temple — —	4125	3419	588
30. *Nebuchadnezzar* struck with Madness — —	4144	3438	569
31. *Daniel*'s Vision of the four Monarchies — —	4158	3452	555
32. *Cyrus* begins to reign in the *Persian* Empire —	4177	3471	536
33. The Battle of *Marathon* — — — — —	4223	3517	490
34. *Artaxerxes Longimanus* begins to reign — —	4249	3543	464
35. The Beginning of *Daniel*'s seventy Weeks of Years	4256	3350	457
36. The Beginning of the *Peloponnesian* War — —	4282	3576	431
37. *Alexander*'s Victory at *Arbela* — — — —	4383	3677	330
38. His Death — — — — — — — —	4390	3684	323
39. The Captivity of 100000 *Jews* by King *Ptolemy*	4393	3687	320
40. The Colossus of *Rhodes* thrown down by an Earthquake — —	4491	3875	222
41. *Antiochus* defeated by *Ptolemy Philopater* — —	4496	3790	217
42. The famous ARCHIMEDES murdered at *Syracuse* —	4506	3800	207
43. *Jason* butchers the Inhabitants of *Jerusalem* —	4543	3837	170
44. *Corinth* plundered and burnt by Consul *Mummius*	4567	386	146
45. *Julius Cæsar* invades *Britain* — — — —	4659	3953	54
46. He corrects the Calendar — — — — —	4677	396	46

47. Is

TABLE I. *Shewing the Golden Number (which is the same both in the Old and New Stile) from the Christian Æra to A. D.* 3800.

Years less than an Hundred.

Hundreds of Years.		0 19 38 57 76 95	1 20 39 58 77 96	2 21 40 59 78 97	3 22 41 60 79 98	4 23 42 61 80 99	5 24 43 62 81	6 25 44 63 82	7 26 45 64 83	8 27 46 65 84	9 28 47 66 85	10 29 48 67 86	11 30 49 68 87	12 31 50 69 88	13 32 51 70 89	14 33 52 71 90	15 34 53 72 91	16 35 54 73 92	17 36 55 74 93	18 37 56 75 94
0	1900	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
100	2000	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5
200	2100	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10
300	2200	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
400	2300	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1
500	2400	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6
600	2500	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11
700	2600	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
800	2700	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2
900	2800	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7
1000	2900	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12
1100	3000	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1200	3100	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3
1300	3200	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8
1400	3300	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13
1500	3400	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1600	3500	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	1	2	3	4
1700	3600	10	11	12	13	14	15	16	17	18	19	1	2	3	4	5	6	7	8	9
1800	3700	15	16	17	18	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14

TABLE II. *Shewing the Number of Direction, for finding Easter Sunday by the Golden Number and Dominical Letter.*

G. N.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	26	19	5	26	12	33	19	12	26	19	5	26	12	5	26	12	33	19	12
B	27	13	6	27	13	34	20	13	27	20	6	27	13	6	20	13	34	20	6
C	28	14	7	21	14	35	21	7	28	21	7	28	14	7	21	14	28	21	7
D	29	15	8	22	15	29	22	8	29	15	8	29	15	1	22	15	29	22	8
E	30	16	2	23	16	30	23	9	30	16	9	23	16	2	23	9	30	23	9
F	24	17	3	24	10	31	24	10	31	17	10	24	17	3	24	10	31	17	10
G	25	18	4	25	11	32	18	11	32	18	4	25	18	4	25	11	32	18	11

This Table is adapted to the New Stile.

TABLE

TABLE III. *Shewing the Dominical Letters, Old Stile, for 4200 Years before the Christian Æra.*

Bef. Christ.				Hundreds of Years.						
Years less than an Hundred.				0 700 1400 2100 2800 3500	100 800 1500 2200 2900 3600	200 900 1600 2300 3000 3700	300 1000 1700 2400 3100 3800	400 1100 1800 2500 3200 3900	500 1200 1900 2600 3300 4000	600 1300 2000 2700 3400 4100
0	28	56	84	D C	C B	B A	A G	G F	F E	E D
1	29	57	85	E	D	C	B	A	G	F
2	30	58	86	F	E	D	C	B	A	G
3	31	59	87	G	F	E	D	C	B	A
4	32	60	88	B A	A G	G F	F E	E D	D C	C B
5	33	61	89	C	B	A	G	F	E	D
6	34	62	90	D	C	B	A	G	F	E
7	35	63	91	E	D	C	B	A	G	F
8	36	64	92	G F	F E	E D	D C	C B	B A	A G
9	37	65	93	A	G	F	E	D	C	B
10	38	66	94	B	A	G	F	E	D	C
11	39	67	95	C	B	A	G	F	E	D
12	40	68	96	E D	D C	C B	B A	A G	G F	F E
13	41	69	97	F	E	D	C	B	A	G
14	42	70	98	G	F	E	D	C	B	A
15	43	71	99	A	G	F	E	D	C	B
16	44	72		C B	B A	A G	G F	F E	E D	D C
17	45	73		D	C	B	A	G	F	E
18	46	74		E	D	C	B	A	G	F
19	47	75		F	E	D	C	B	A	G
20	48	76		A G	G F	F E	E D	D C	C B	B A
21	49	77		B	A	G	F	E	D	C
22	50	78		C	B	A	G	F	E	D
23	51	79		D	C	B	A	G	F	E
24	52	80		F E	E D	D C	C B	B A	A G	G F
25	53	81		G	F	E	D	C	B	A
26	54	82		A	G	F	E	D	C	B
27	55	83		B	A	G	F	E	D	C

TABLE IV. *Shewing the Dominical Letters, Old Stile, for 4200 Years after the Christian Æra.*

After Christ.				Hundreds of Years.						
Years less than an Hundred.				0 700 1400 2100 2800 3500	100 800 1500 2200 2900 3600	200 900 1600 2300 3000 3700	300 1000 1700 2400 3100 3800	400 1100 1800 2500 3200 3900	500 1200 1900 2600 3300 4000	600 1300 2000 2700 3400 4100
0	28	56	84	D C	E D	F E	G F	A G	B A	C B
1	29	57	85	B	C	D	E	F	G	A
2	30	58	86	A	B	C	D	E	F	G
3	31	59	87	G	A	B	C	D	E	F
4	32	60	88	F E	G F	A G	B A	C B	D C	E D
5	33	61	89	D	E	F	G	A	B	C
6	34	62	90	C	D	E	F	G	A	B
7	35	63	91	B	C	D	E	F	G	A
8	36	64	92	A G	B A	C B	C D	E D	F E	G F
9	37	65	93	F	G	A	B	C	D	E
10	38	66	94	E	F	G	A	B	C	D
11	39	67	95	D	E	F	G	A	B	C
12	40	68	96	C B	D C	E D	F E	G F	A G	B A
13	41	69	97	A	B	C	D	E	F	G
14	42	70	98	G	A	B	C	D	E	F
15	43	71	99	F	G	A	B	C	D	E
16	44	72		E D	F E	G F	A G	B A	C B	D C
17	45	73		C	D	E	F	G	A	B
18	46	74		B	C	D	E	F	G	A
19	47	75		A	B	C	D	E	F	G
20	48	76		G F	A G	B A	C B	D C	E D	F E
21	49	77		E	F	G	A	B	C	D
22	50	78		D	E	F	G	A	B	C
23	51	79		C	D	E	F	G	A	B
24	52	80		B A	C B	D C	E D	F E	G F	A G
25	53	81		G	A	B	C	D	E	F
26	54	82		F	G	A	B	C	D	E
27	55	83		E	F	G	A	B	C	D

TABLE

TABLE V. *The Dominical Letter, New Stile, for 4000 Years after the Christian Æra.*

After Christ.				Hundreds of Years.			
Years less than an Hundred.				100	200	300	400
				500	600	700	800
				900	1000	1100	1200
				1300	1400	1500	1600
				1700	1800	1900	2000
				2100	2200	2300	2400
				2500	2600	2700	2800
				2900	3000	3100	3200
				3300	3400	3500	3600
				3700	3800	3900	4000
				C	E	G	B A
1	29	57	85	B	D	F	G
2	30	58	86	A	C	E	F
3	31	59	87	G	B	D	E
4	32	60	88	F E	A G	C B	D C
5	33	61	89	D	F	A	B
6	34	62	90	C	E	G	A
7	35	63	91	B	D	F	G
8	36	64	92	A G	C B	E D	F E
9	37	65	93	F	A	C	D
10	38	66	94	E	G	B	C
11	39	67	95	D	F	A	B
12	40	68	96	C B	E D	G F	A G
13	41	69	97	A	C	E	F
14	42	70	98	G	B	D	E
15	43	71	99	F	A	C	D
16	44	72		E D	G F	B A	C B
17	45	73		C	E	G	A
18	46	74		B	D	F	G
19	47	75		A	C	E	F
20	48	76		G F	B A	D C	E D
21	49	77		E	G	B	C
22	50	78		D	F	A	B
23	51	79		C	E	G	A
24	52	80		B A	D C	F E	G F
25	53	81		G	B	D	E
26	54	82		F	A	C	D
27	55	83		E	G	B	C
28	56	84		D C	F E	A G	B A

TABLE VI. *Shewing the Days of the Months for both Stiles by the Dominical Letters.*

Week Day.	A	B	C	D	E	F	G
	1	2	3	4	5	6	7
	8	9	10	11	12	13	14
January 31	15	16	17	18	19	20	21
October 31	22	23	24	25	26	27	28
	29	30	31				
				1	2	3	4
	5	6	7	8	9	10	11
Feb. 28-29	12	13	14	15	16	17	18
March 31	19	20	21	22	23	24	25
November 30	26	27	28	29	30	31	
							1
	2	3	4	5	6	7	8
	9	10	11	12	13	14	15
April 30	16	17	18	19	20	21	22
July 31	23	24	25	26	27	28	29
	30	31					
			1	2	3	4	5
	6	7	8	9	10	11	12
	13	14	15	16	17	18	19
Auguſt 31	20	21	22	23	24	25	26
	27	28	29	30	31		
						1	2
	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
September 30	17	18	19	20	21	22	23
December 31	24	25	26	27	28	29	30
	31						
		1	2	3	4	5	6
	7	8	9	10	11	12	13
	14	15	16	17	18	19	20
May 31	21	22	23	24	25	26	27
	28	29	30	31			
					1	2	3
	4	5	6	7	8	9	10
	11	12	13	14	15	16	17
June 30	18	19	20	21	22	23	24
	25	26	27	28	29	30	

CHAP. XXII.

A Description of the Astronomical Machinery serving to explain and illustrate the foregoing part of this Treatise.

Fronting the Title Page. The ORRERY.

397. THE ORRERY. This Machine shews the Motions of the Sun, Mercury, Venus, Earth, and Moon; and occasionally, the superior Planets, Mars, Jupiter, and Saturn, may be put on; Jupiter's four Satellites are moved round him in their proper times by a small Winch; and Saturn has his five Satellites, and his Ring which keeps it's Parallelism round the Sun; and by a Lamp put in the Sun's place, the Ring shews all the Phases described in the 204th Article.

The Sun.

In the Center, No. 1. represents the SUN, supported by it's Axis inclining almost 8 Degrees from the Axis of the Ecliptic; and turning round in $25\frac{1}{4}$ days on it's Axis, of which the North Pole inclines toward the 8th Degree of Pisces in the great Ecliptic (No. 11.) whereon the Months and Days are engraven over the Signs and Degrees in which the Sun appears, as seen from the Earth, on the different days of the year.

The Ecliptic.

Mercury.

The nearest Planet (No. 2.) to the Sun is *Mercury*, which goes round him in 87 days 23 hours, or $87\frac{23}{24}$ diurnal rotations of the Earth; but has no Motion round it's Axis in the Machine, because the time of it's diurnal Motion in the Heavens is not known to us.

Venus.

The next Planet in order is *Venus* (No. 3.) which performs her annual Course in 224 days 17 hours; and turns round her Axis in 24 days 8 hours, or in $24\frac{1}{3}$ diurnal rotations of the Earth. Her Axis inclines 75 Degrees from the Axis of the Ecliptic, and her North Pole inclines towards the 20th Degree of Aquarius, according to the observations of *Bianchini.*

Bianchini. She ſhews all the Phenomena deſcribed from the 30th to the 44th Article in Chap. I.

Next without the Orbit of Venus is the *Earth*, (No. 4.) which turns round it's Axis, to any fixed point at a great diſtance, in 23 hours 56 minutes 4 ſeconds, of mean ſolar time (§ 221, *& ſeq.)* but from the Sun to the Sun again in 24 hours of the ſame time. No. 6. is a ſydereal Dial-Plate under the Earth; and No. 7. a ſolar Dial-Plate on the cover of the Machine. The Index of the former ſhews ſydereal, and of the latter, ſolar time; and hence, the former Index gains one entire revolution on the latter every year, as 365 ſolar or natural days contain 366 ſydereal days, or apparent revolutions of the Stars. In the time that the Earth makes 365¼ diurnal rotations on it's Axis, it goes once round the Sun in the Plane of the Ecliptic; and always keeps oppoſite to a moving Index (No. 10.) which ſhews the Sun's apparent daily change of place, and alſo the days of the months. **The Earth.**

The Earth is half covered with a black cap, for dividing the apparently enlightened half next the Sun from the other half, which when turned away from him is in the dark. The edge of the cap repreſents *the Circle bounding Light and Darkneſs*, and ſhews at what time the Sun riſes and ſets to all places throughout the year. The Earth's Axis inclines 23½ Degrees from the Axis of the Ecliptic, the North Pole inclines toward the beginning of Cancer, and keeps it's Paralleliſm throughout it's annual Courſe, § 48, 202; ſo that in Summer the northern parts of the Earth incline towards the Sun, and in Winter from him: by which means, the different lengths of days and nights, and the cauſe of the various ſeaſons, are demonſtrated to ſight.

There is a broad Horizon, to the upper ſide of which is fixed a Meridian ſemicircle in the North and South Points, graduated on both ſides from the Horizon to 90° in the Zenith, or vertical Point.

The edge of the Horizon is graduated from the East and West to the South and North Points, and within these Divisions are the Points of the Compass. From the lower side of this thin Horizon-Plate stand out four small Wires, to which is fixed a Twilight-Circle 18 Degrees from the graduated side of the Horizon all round. This Horizon may be put upon the Earth (when the cap is taken away) and rectified to the Latitude of any place: and then, by a small Wire called *the Solar Ray*, which may be put on so as to proceed directly from the Sun's Center towards the Earth's, but to come no farther than almost to touch the Horizon. The beginning of Twilight, time of Sun-rising, with his Amplitude, Meridian Altitude, Time of Setting, Amplitude then, and End of Twilight, are shewn for every day of the year, at *that* place to which the Horizon is rectified.

The Moon. The Moon (No. 5.) goes round the Earth, from between it and any fixed point at a great distance, in 27 days 7 hours 43 minutes, or through all the Signs and Degrees of her Orbit; which is called *her Periodical Revolution*; but she goes round from the Sun to the Sun again, or from Change to Change, in 29 days 12 hours 45 minutes, which is *her Synodical Revolution*; and in that time she exhibits all the Phases already described, § 255.

When the above-mentioned Horizon is rectified to the Latitude of any given place, the Times of the Moon's rising and setting, together with her Amplitude, are shewn to that place as well as the Sun's; and all the various Phenomena of the Harvest-Moon, § 273, & *seq.* are made obvious to sight.

The Nodes. The Moon's orbit (No. 9.) is inclined to the Ecliptic, (No. 11.) one half being above, and the other below it. The Nodes, or Points at o and o, lie in the Plane of the Ecliptic, as described § 317, 318, and shift backward through all it's Sines and Degrees in 18⅔ years. The Degrees of the Moon's

Latitude,

Latitude, to the highest at *N L* (North Latitude) and lowest at *S L* (South Latitude) are engraven both ways from her Nodes at ☊ and ☋; and, as the Moon rises and falls in her Orbit according to it's inclination, her Latitude and Distance from her Nodes are shewn for every day; having first rectified her Orbit so as to set the Nodes to their proper places in the Ecliptic: and then, as they come about at different, and almost opposite times of the year, § 319, and point twice towards the Sun, all the Eclipses may be shewn for hundreds of years (without any new rectification) by turning the Machinery backward for time past, or forward for time to come. At 17 Degrees distance from each Node, on both sides, is engraved a small Sun; and at 12 Degrees distance, a small Moon; which shew the limits of solar and lunar Eclipses, § 317: and when, at any change, the Moon falls between either of these Suns and the Node, the Sun will be eclipsed on the day pointed to by the Annual-Index (No. 10.) and as the Moon has then North or South Latitude, one may easily judge whether that Eclipse will be visible in the Northern or Southern Hemisphere; especially as the Earth's Axis inclines toward the Sun or from him at that time. And when, at any Full, the Moon falls between either of the little Moons and Node, she will be eclipsed, and the Annual-Index shews the day of that Eclipse. There is a Circle of $29\frac{1}{2}$ equal parts (No. 8.) on the cover of the Machine, on which an Index shews the days of the Moon's age.

A semi-ellipsis and semi-circle are fixed to an elliptical ring, which being put like a cap upon the Earth, and the forked part *F* upon the Moon, shews the Tides as the Earth turns round within them, and they are led round it by the Moon. When the different places come to the semi-ellipsis *A a E b B*, they have Tides of Flood; and when they come to the semicircle *C E D*, they have Tides of Ebb, PLATE IX. Fig. X.

 § 304,

The Earth is half covered with a black cap *a*, as in the former Orrery, for dividing the day from the night; and, as the different places come out from below the edge of the cap, or go in below it, they ſhew the times of Sun-riſing and ſetting every day of the year. This cap is fixed on the wire *b*, which has a forked piece *C* turning round the wire *d*: and, as the Earth goes round the Sun, it carries the Cap, Wire, and ſolar Ray round him; ſo that the ſolar Ray conſtantly points towards the Earth's Center.

On the Axis of the pinion *k* is the pinion *m*, which turns a wheel on the cock or ſupporter *n*, and on the Axis of this wheel neareſt *n* is a pinion (hid from view) under the Plate *C*, which pinion turns a wheel that carries the Moon *V* round the Earth *U*; the Moon's Axis riſing and falling in the ſocket *W*, which is fixed to the triangular piece above *Z*; and this piece is fixed to the top of the Axis of the laſt-mentioned wheel. The ſocket *W* is ſlit on the outermoſt ſide; and in this ſlit the two pins near *Y*, fixed in the Moon's Axis, move up and down; one of them being above the inclined Plane *Y X*, and the other below it. By this mechaniſm, the Moon *V* moves round the Earth *T* in the inclined Orbit *q*, parallel to the Plane of the Ring *Y X*; of which the Deſcending Node is at *X*, and the Aſcending Node oppoſite to it, but hid by the ſupporter *X* 2.

The ſmall wheel *E* turns the large wheels *D* and *F*, of equal diameters, by cat-gut ſtrings croſſing between them: and the Axes of theſe two wheels are cranked at *G* and *H*, above the Plate *B*. The upright ſtems of theſe cranks going through the Plate *C*, carry it over and over the fixed Plate *B*, with a motion which carries the Earth *U* round the Sun *T*, keeping the Earth's Axis always parallel to itſelf; or ſtill inclining towards the left hand of the Plate; and ſhewing the viciſſitudes of ſeaſons, as deſcribed in the tenth chapter. As the Earth goes round the Sun, the pinion *k* goes round the wheel *i*; for the Axis of *k* never touches the fixed Plate *B*, but turns on a wire fixed into the Plate *C*.

On the top of the crank *G* is an Index *L*, which goes round the Circle *m* 2 in the time that the Earth goes round the Sun, and points to the days of the months; which, together with the names of the ſeaſons, are marked in this Circle.

This Index has a ſmall grooved wheel *L* fixed upon it, round which, and the Plate *Z*, goes a cat-gut ſtring croſſing between them; and by this means the Moon's inclined Plane *Y X* with it's Nodes is turned backward, for ſhewing the times and returns of Eclipſes, § 319, 320.

The following parts of this machine muſt be conſidered as diſtinct from thoſe already deſcribed.

Towards the right hand, let *S* be the Earth hung on the wire *e*, which is fixed into the Plate *B*; and let *O* be the Moon fixed on the Axis *M*, and turning round within the cap *P*, in which, and in the Plate *C*, the crooked wire *Q* is fixed. On the Axis *M* is alſo fixed the Index *K*, which goes round a Circle *h* 2, divided into 29½ equal parts, which are the days of the Moon's age: but to avoid confuſion in the ſcheme, it is only marked with the numeral figures 1 2 3 4, for the Quarters. As the crank *H* carries this Moon round the Earth *S* in the Orbit *t*, ſhe ſhews all her Phaſes by means of the cap *P* for the different days of her age, which are ſhewn by the Index *K*; this Index, turning juſt as the Moon *O* does, demonſtrates her turning round her Axis, as ſhe ſtill keeps the ſame ſide towards the Earth *S*, § 262.

At the other end of the Plate *C*, a Moon *N* goes round an Earth *R* in the Orbit *p*. But this Moon's Axis is ſtuck faſt into the Plate *C* at *S* 2, ſo that neither Moon nor Axis can turn round; and as this Moon goes round her Earth, ſhe ſhews herſelf all round to it; which proves, that if the Moon

was

was ſeen all round from the Earth in a Lunation, ſhe could not turn round her Axis.

N. B. If there were only the two wheels *D* and *F*, with a cat-gut ſtring over them, but not croſſing between them, the Axis of the Earth *U* would keep it's Paralleliſm round the Sun *T*, and ſhew all the ſeaſons; as I ſometimes make theſe Machines: and the Moon *O* would go round the Earth *S*, ſhewing her Phaſes as above; as likewiſe would the Moon *N* round the Earth *R*; but then, neither could the diurnal motion of the Earth *U* on it's Axis be ſhewn, nor the motion of the Moon *V* round the Earth.

399. In the year 1746 I contrived a very ſimple Machine, and deſcribed it's performance in a ſmall Treatiſe upon the Phenomena of the Harveſt-Moon, publiſhed in the year 1747. I improved it ſoon after, by adding another wheel, and called it *The Calculator*. It may be eaſily made by any Gentleman who has a mechanical Genius. The CALCULATOR.

The great flat Ring ſupported by twelve pillars, and on which the twelve Signs with their reſpective Degrees are laid down, is the Ecliptic; nearly in the center of it is the Sun *S* ſupported by the ſtrong crooked Wire *I*; and from the Sun proceeds a Wire *W*, called *the Solar Ray*, pointing towards the center of the Earth *E*, which is furniſhed with a moveable Horizon *H*, together with a braſen Meridian, and Quadrant of Altitude. *R* is a ſmall Ecliptic, whoſe Plane co-incides with that of the great one, and has the like Signs and Degrees marked upon it; and is ſupported by two Wires *D* and *D*, which are put into the Plate *PP*, but may be taken off at pleaſure. As the Earth goes round the Sun, the Signs of this ſmall Circle keep parallel to themſelves, and to thoſe of the great Ecliptic. When it is taken off, and the ſolar Ray *W* drawn farther out, ſo as almoſt to touch the Horizon *H*, or the Quadrant of Altitude, the Horizon being PLATE VIII. Fig. I.

being rectified to any given Latitude, and the Earth turned round it's Axis by hand, the point of the Wire *W* shews the Sun's Declination in passing over the graduated brass Meridian, and his height at any given time upon the Quadrant of Altitude, together with his Azimuth, or Point of bearing upon the Horizon at that time; and likewise his Amplitude, and time of rising and setting by the Hour-Index, for any day of the year that the Annual-Index *U* points to in the Circle of Months below the Sun. *M* is a Solar-Index or Pointer supported by the wire *L* which is fixed into the knob *K*: the use of this Index is to shew the Sun's place in the Ecliptic every day in the year; for it goes over the Signs and Degrees as the Index *U* goes over the Months and Days; or rather, as they pass under the Index *U*, in moving the cover plate with the Earth and it's Furniture round the Sun; for the Index *U* is fixed tight on the immoveable Axis in the Center of the Machine. *K* is a knob or handle for moving the Earth round the Sun, and the Moon round the Earth.

As the Earth is carried round the Sun, it's Axis constantly keeps the same oblique direction, or parallel to itself, § 48, 202, shewing thereby the different lengths of days and nights at different times of the year, with all the various seasons. And, in one annual revolution of the Earth, the Moon *M* goes $12\frac{1}{3}$ times round it from Change to Change, having an occasional provision for shewing her different Phases. The lower end of the Moon's Axis bears by a small friction wheel upon the inclined Plane *T*, which causes the Moon to rise above and sink below the Ecliptic *R* in every Lunation; crossing it in her Nodes, which shift backward through all the Signs and Degrees of the said Ecliptic, by the retrograde Motion of the inclined Plane *T*, in 18 years and 225 days. On this Plane the Degrees and Parts of the Moon's North and South Latitude are laid down from both the Nodes,

one

one of which, viz. the Defcending Node, appears at o, by *D N* above *B*; the other Node being hid from Sight on this Plane by the plate *P P*; and from both Nodes, at proper diftances, as in the other Orrery, the limits of Eclipfes are marked, and all the folar and lunar Eclipfes are fhewn in the fame manner, for any given year, within the limits of 6000, either before or after the Chriftian Æra. On the plate that covers the wheel-work, under the Sun *S*, and round the knob *K*, are Aftronomical Tables, by which the Machine may be rectified to the beginning of any given year within thefe limits, in three or four minutes of time; and when once fet right, may be turned backward for 300 years paft, or forward for as many to come, without requiring any new rectification. There is a method for it's adding up the 29th of *February* every fourth year, and allowing only 28 days to that month for every other three: but all this being performed by a particular manner of cutting the teeth of the Wheels, and dividing the the Month-Circle, too long and intricate to be defcribed here, I fhall only fhew how thefe motions may be performed near enough for common ufe, by wheels with grooves and cat-gut ftrings round them; only here I muft put the Operator in mind, that the grooves are to be made fharp (not round) bottomed, to keep the ftrings from flipping.

The Moon's Axis moves up and down in the focket *N* fixed into the bar *O* (which carries her round the Earth) as fhe rifes above or finks below the Ecliptic; and immediately below the inclined Plane *T* is a flat circular plate (between *Y* and *T*) on which the different Excentricities of the Moon's Orbit are laid down; and likewife her mean Anomaly and elliptic Equation, by which her true Place may be very nearly found at any time. Below this Apogee plate, which fhews the Anomaly, &c. is a Circle *Y* divided into 29½ equal parts,

5 which

which are the days of the Moon's age: and the forked end *A* of the Index *AB* (Fig. II.) may be put into the apogee part of this plate; there being juſt ſuch another Index to put into the inclined Plane *T* at the Aſcending Node; and then the curved points *B* of theſe Indexes ſhew the direct Motion of the Apogee, and retrogade Motion of the Nodes through the Ecliptic *R*, with their Places in it at any given time. As the Moon *M* goes round the Earth *E*, ſhe ſhews her Place every day in the Ecliptic *R*, and the lower end of her Axis ſhews her Latitude and Diſtance from her Node on the inclined Plane *T*, alſo her Diſtance from her Apogee and Perigee, together with her mean Anomaly, the then Excentricity of her Orbit, and her elliptic Equation, all on the Apogee plate, and the Day of her Age in the Circle *Y* of 29½ equal parts; for every day of the year pointed out by the Annual-Index *U* in the Circle of months.

Having rectified the Machine by the Tables for the beginning of any year, move the Earth and Moon forward by the knob *K*, until the Annual-Index comes to any given day of the month; then ſtop, and not only all the above Phenomena may be ſhewn for that day, but alſo, by turning the Earth round it's Axis, the Declination, Azimuth, Amplitude, Altitude of the Moon at any hour, and the Times of her riſing and ſetting, are ſhewn by the Horizon, Quadrant of Altitude, and Hour-Index. And in moving the Earth round the Sun, the days of all the New and Full Moons and Eclipſes in any given year are ſhewn. The Phenomena of the Harveſt-Moon, and thoſe of the Tides, by ſuch a cap as that in Plate IX. Fig. 10. put upon the Earth and Moon, together with the ſolution of many problems not here related, are made conſpicuous.

The eaſieſt, though not the beſt way, that I can inſtruct any mechanical perſon to make the wheel-work of ſuch a machine, is as follows; which is the

the way that I made it, before I thought of numbers exact enough to make it worth the trouble of cutting teeth in the wheels.

Fig. 3d of Plate VIII. is a section of this Machine; in which *ABCD* is a frame of wood held together by four pillars at the corners, whereof two appear at *AC* and *BD*. In the lower Plate *CD* of this frame are three small friction-wheels, at equal distances from each other; two of them appearing at *e* and *e*. As the frame is moved round, these wheels run upon the fixed bottom Plate *EE*, which supports the whole work. PLATE VIII. Fig. III.

In the center of this last-mentioned Plate is fixed the upright Axis *GFFf*, and on the same Axis is fixed the Wheel *HHH*, in which are four Grooves, *I*, *X*, *k*, *L* of different diameters. In these Grooves are cat-gut strings going also round the separate Wheels *M*, *N*, *O* and *P*.

The Wheel *M* is fixed on a solid Spindle or Axis, the lower pivot of which turns at *R* in the under Plate of the moveable frame *ABCD*; and on the upper end of this Axis is fixed the Plate *o o* (which is *PP*, under the Earth, in Fig. 1.) and to this Plate is fixed, at an Angle of $23\frac{1}{2}$ Degrees inclination, the Dial-plate below the Earth *T*; on the Axis of which, the Index *q* is turned round by the Earth. This Axis, together with the Wheel *M*, and Plate *o o*, keep their Parallelism in going round the Sun *S*.

On the Axis of the Wheel *M* is a moveable socket, on which the small Wheel *N* is fixed, and on the upper end of this socket is put on tight (but so as it may be occasionally turned by hand) the bar *Z Z* (viz. the bar *O* in Fig. 1.) which carries the Moon *m* round the Earth *T*, by the socket *n*, fixed into the bar. As the Moon goes round the Earth, her Axis rises and falls in the socket *n*; because, on the lower end of her Axis, which is turned inward, there is a small friction Wheel *s* running on the inclined Plane *X* (which is *T* in Fig. 1.) and

so

fo caufes the Moon alternately to rife above and fink below the little Ecliptic *VV* (*R* in Fig. 1.) in every Lunation.

On the focket or hollow axis of the Wheel *N*, there is another focket, on which the Wheel *O* is fixed; and the Moon's inclined Plane *X* is put tightly on the upper end of this focket, not on a fquare, but on a round, that it may be occafionally fet by hand without wrenching the Wheel or Axle.

Laftly, on the hollow Axis of the Wheel *O* is another focket, on which is fixed the Wheel *P*, and on the upper end of this focket is put on tightly the Apogee plate *Y* (*that* immediately below *T* in Fig. 1.) All thefe Axles turn in the upper Plate of the moveable frame at *Q*; which Plate is covered with the thin Plate *cc* (fcrewed to it) whereon are the fore-mentioned Tables and Month-Circle in Fig. 1.

The middle part of the thick fixed Wheel *HHH* is much broader than the reft of it, and comes out between the Wheels *M* and *O* almoft to the Wheel *N*. To adjuft the diameters of the Grooves of this fixed Wheel to the Grooves of the feparate Wheels *M*, *N*, *O* and *P*, fo as they may perform their motions in the proper times, the following method muft be obferved.

The Groove of the Wheel *M*, which keeps the Parallelifm of the Earth's Axis, muft be precifely of the fame Diameter as the lower Groove *I* of the fixed Wheel *HHH*; but, when this Groove is fo well adjufted as to fhew, that in ever fo many annual revolutions of the Earth, it's Axis keeps it's Parallelifm, as may be obferved by the folar Ray *W* (Fig. 1.) always coming precifely to the fame Degree of the fmall Ecliptic *R* at the end of every annual revolution, when the Index *M* points to the like Degree in the great Ecliptic; then, with the edge of a thin File, give the Groove of the Wheel *M* a fmall rub all round, and, by that means lef-

fening

ſening the Diameter of the Groove perhaps about the 20th part of a hair's breadth, it will cauſe the Earth to ſhew the Preceſſion of the Equinoxes; which, in many annual revolutions, will begin to be ſenſible, as the Earth's Axis deviates ſlowly from it's Paralleliſm, § 246, towards the antecedent Signs of the Ecliptic.

The Diameter of the Groove of the Wheel *N*, which carries the Moon round the Earth, muſt be to the Diameter of the Groove *X*, as a Lunation is to a year; that is, as $29\frac{1}{2}$ to $365\frac{1}{4}$.

The Diameter of the Groove of the Wheel *O*, which turns the inclined Plane *X* with the Moon's Nodes backward, muſt be to the Diameter of the Groove *k*, as 20 to $18\frac{225}{365}$. And,

Laſtly, the Diameter of the Groove of the Wheel *P*, which carries the Moon's Apogee forward, muſt be to the Diameter of the Groove *L*, as 70 to 62.

But, after all this nice adjuſtment of the Grooves to the proportional times of their reſpective Wheels turning round, and which ſeems to promiſe very well in Theory, there will ſtill be found a neceſſity of a farther adjuſtment by hand; becauſe proper allowance muſt be made for the Diameters of the cat-gut ſtrings: and the Grooves muſt be ſo adjuſted by hand, as, that in the time the Earth is moved once round the Sun, the Moon muſt perform 12 ſynodical revolutions round the Earth, and be almoſt 11 days old in her 13th revolution. The inclined Plane with it's Nodes muſt go once round backward through all the Signs and Degrees of the ſmall Ecliptic in 18 annual revolutions of the Earth, and 225 days over. And the Apogee plate muſt go once round forward, ſo as it's Index may go over all the Signs and Degrees of the ſmall Ecliptic in eight years (or ſo many annual revolutions of the Earth) and 312 days over.

N. B. The ſtring which goes round the Grooves *X* and *N* for the Moon's Motion muſt croſs between theſe wheels; but all the reſt of the ſtrings

go

go in their reſpective Grooves, IM, kO, and LP, without croſſing.

The COMETARIUM. 400. The COMETARIUM. This curious Machine ſhews the Motion of a Comet or excentric Body moving round the Sun, deſcribing equal areas in equal times, § 152, and may be ſo contrived as to ſhew ſuch a Motion for any Degree of Excentricity. It was invented by the late Dr. DESAGULIERS.

PLATE IV. Fig. IV. The dark elliptical Groove round the letters *a b c d e f g h i k l m* is the Orbit of the Comet Y: this Comet is carried round in the Groove, according to the order of letters, by the Wire W fixed in the Sun S, and ſlides on the Wire as it approaches nearer to or recedes farther from the Sun, being neareſt of all in the Perihelion a, and fartheſt in the Aphelion g. The areas aSb, bSc, cSd, &c. or contents of theſe ſeveral Triangles, are all equal; and in every turn of the Winch N the Comet Y is carried over one of theſe areas; conſequently in as much time as it moves from f to g, or from g to h, it moves from m to a, or from a to b; and ſo of the reſt, being quickeſt of all at a, and ſloweſt at g. Thus, the Comet's velocity in it's Orbit continually decreaſes from the Perihelion a to the Aphelion g; and increaſes in the ſame proportion from g to a.

The elliptic Orbit is divided into 12 equal Parts or Signs, with their reſpective Degrees, and ſo is the Circle *n o p q r s t n*, which repreſents a great Circle in the Heavens, and to which the Comet's motion is referred by a ſmall knob on the point of the wire W. Whilſt the Comet moves from f to g in it's Orbit, it appears to move only about five degrees in this Circle, as is ſhewn by the ſmall knob on the end of the Wire W; but in the like time, as the Comet moves from m to a, or from a to b, it appears to deſcribe the large ſpace tn or no in the Heavens, either of which ſpaces contains 120 Degrees, or four Signs. Were the Excentricity of of it's Orbit greater, the greater ſtill would be the difference of it's Motion, and *vice verſâ.*

ABCDEFGHIKLMA is a circular Orbit for ſhewing the equable Motion of a Body round the Sun *S*, deſcribing equal Areas *ASB*, *BSC*, &c. in equal times with thoſe of the Body *Y* in it's elliptical Orbit above-mentioned; but with this difference, that the circular Motion deſcribes the equal Arcs *AB*, *BC*, &c. in the ſame equal times that the elliptical Motion deſcribes the unequal Arcs *ab*, *bc*, &c.

Now, ſuppoſe the two Bodies *Y* and 1 to ſtart from the Points *a* and *A* at the ſame moment of time, and each having gone round it's reſpective Orbit, to arrive at theſe Points again at the ſame inſtant, the Body *Y* will be forwarder in it's Orbit than the Body 1 all the way from *a* to *g*, and from *A* to *G*; but 1 will be forwarder than *Y* through all the other half of the Orbit; and the difference is equal to the Equation of the Body *Y* in it's Orbit. At the Points *a*, *A*, and *g*, *G*, that is, in the Perihelion and Aphelion, they will be equal; and then the Equation vaniſhes. This ſhews why the Equation of a Body moving in an elliptic Orbit, is added to the mean or ſuppoſed circular Motion from the Perihelion to the Aphelion, and ſubtracted from the Aphelion to the Perihelion, in Bodies moving round the Sun, or from the Perigee to the Apogee, and from the Apogee to the Perigee in the Moon's Motion round the Earth, according to the Precepts in the 353d Article; only we are to conſider, that when Motion is turned into Time, it reverſes the titles in the Table of *The Moon's elliptic Equation.*

This Motion is performed in the following manner by the machine. *ABC* is a wooden bar (in the box containing the wheel-work) above which are the Wheels *D* and *E*; and below it the elliptic Plates *FF* and *GG*; each Plate being fixed on an Axis in one of it's Focuſes, at *E* and *K*; and the Wheel *E* is fixed on the ſame Axis with the Plate PLATE IV. Fig. V.

FF. Theſe Plates have Grooves round their edges preciſely of equal diameters to one another, and in theſe Grooves is the cat-gut ſtring *gg*, *gg* croſſing between the Plates at *h*. On *H*, (the Axis of the handle or winch *N* in Fig. 4th,) is an endleſs ſcrew in Fig. 5, working in the Wheels *D* and *E*, whoſe numbers of teeth being equal, and ſhould be equal to the number of lines *a S*, *b S*, *c S*, &c. in Fig. 4, they turn round their Axes in equal times to one another, and to the Motion of the elliptic Plates. For, the Wheels *D* and *E* having equal numbers of teeth, the Plate *FF* being fixed on the ſame Axis with the Wheel *E*, and the Plate *FF* turning the equally big Plate *GG* by a cat-gut ſtring round them both, they muſt all go round their Axes in as many turns of the handle *N* as either of the Wheels has teeth.

It is eaſy to ſee, that the end *h* of the elliptical Plate *FF* being farther from it's Axis *E* than the oppoſite end *i* is, muſt deſcribe a Circle ſo much the larger in proportion; and muſt therefore move through ſo much more ſpace in the ſame time; and for that reaſon the end *h* moves ſo much faſter than the end *i*, although it goes no ſooner round the Center *E*. But then, the quick-moving end *h* of the Plate *FF* leads about the ſhort end *h K* of the Plate *GG* with the ſame velocity; and the ſlow moving end *i* of the Plate *FF* coming half round as to *B*, muſt then lead the long end *k* of the Plate *GG* as ſlowly about: So that the elliptical Plate *FF* and it's Axis *E* move uniformly and equally quick in every part of it's revolution; but the elliptical Plate *GG*, together with it's Axis *K*, muſt move very unequally in different parts of it's revolution; the difference being always inverſely as the diſtance of any point of the Circumference of *GG* from it's Axis at *K*: or in other words, to inſtance in two points, if the diſtance *Kk* be four, five, or ſix times as great as the diſtance *Kh*, the Point *h* will move in that poſition four, five, or ſix times

N and *O*, having two little Balls on their ends for the Sun and Moon, as in the Figure. The Collet *D* is fixed to the circular Plate *F*, whereon the 29½ days of the Moon's age are engraven, beginning juſt under the Sun's Wire *N*; and as this Wire is moved round the Globe, the Plate *F* turns round with it. Theſe Wires are eaſily turned, if the ſcrew *G* be ſlackened; and when they are ſet to their proper places, the ſcrew ſerves to fix them there ſo, as in turning the Ball of the Globe, the Wires with the Sun and Moon go round with it; and theſe two little Balls riſe and ſet at the ſame times, and on the ſame points of the Horizon, for the day to which they are rectified, as the Sun and Moon do in the Heavens.

Becauſe the Moon keeps not her courſe in the Ecliptic (as the Sun appears to do) but has a Declination of 5⅓ Degrees on each ſide from it in every Lunation, § 317, her Ball may be ſcrewed as many Degrees to either ſide of the Ecliptic as her Latitude or Declination from the Ecliptic amounts to at any given time; and for this purpoſe *S* is a ſmall piece of paſteboard, of which the curved edge at *S* is to be ſet upon the Globe at right Angles to the Ecliptic, and the dark line over *S* to ſtand upright upon it. From this line, on the convex edge, are drawn the 5⅓ Degrees of the Moon's Latitude on both ſides of the Ecliptic; and when this piece is ſet upright on the Globe, it's graduated edge reaches to the Moon on the Wire *O*, by which means ſhe is eaſily adjuſted to her Latitude found by an Ephemeris.

The Horizon is ſupported by two ſemicircular Arches, becauſe Pillars would ſtop the progreſs of the Balls when they go below the Horizon in an oblique ſphere.

To rectify it. *To rectify this Globe.* Elevate the Pole to the Latitude of the Place; then bring the Sun's place in the Ecliptic for the given day to the braſen Meridian, and ſet the Hour-Index to XII at noon, that

ſo that the Globe may not be liable to ſhake; to prevent which, the Pedeſtal is about two Inches thick, and the Axis goes quite through it, bearing on a ſhoulder. The Globe is hung in a graduated braſen Meridian, much in the uſual way; and the thin Plate *N*, *N E*, *E* is a moveable Horizon, graduated round the outer edge, for ſhewing the Bearings and Amplitudes of the Sun, Moon, and Planets. The braſen Meridian is grooved round the outer edge; and in this Groove is a ſlender ſemicircle of braſs, the ends of which are fixed to the Horizon in its North and South Points: this ſemicircle ſlides in the Groove as the Horizon is moved in rectifying it for different Latitudes. To the middle of the ſemi-circle is fixed a Pin, which always keeps in the Zenith of the Horizon, and on this Pin, the Quadrant of Altitude *q* turns; the lower end of which, in all poſitions, touches the Horizon as it is moved round the ſame. This Quadrant is divided into 90 Degrees from the Horizon to the zenithal Pin on which it is turned, at 90. The great flat Circle or Plate *A B* is the Ecliptic, on the outer edge of which the Signs and Degrees are laid down; and every fifth Degree is drawn through the reſt of the ſurface of this Plate towards it's Center. On this Plate are ſeven Grooves, to which ſeven little Balls are adjuſted by ſliding Wires, ſo that they are eaſily moved in the Grooves, without danger of ſtarting out of them. The Ball next the terreſtrial Globe is the Moon, the next without it is Mercury, the next Venus, the next the Sun, then Mars, then Jupiter, and laſtly Saturn; and in order to know them, they are ſeparately ſtampt with the following Characters; ☾, ☿, ♀, ☉, ♂, ♃, ♄. This Plate or Ecliptic is ſupported by four ſtrong Wires, having their lower ends fixed into the Pedeſtal, at *C*, *D*, and *E*, the fourth being hid by the Globe. The Ecliptic is inclined $23\frac{1}{2}$ Degrees to the Pedeſtal, and is therefore

fore properly inclined to the Axis of the Globe which ſtands upright on the Pedeſtal.

To rectify this Machine. Set the Sun, and all the planetary Balls, to their geocentric places in the Ecliptic for any given time, by an Ephemeris: then ſet the North Point of the Horizon to the Latitude of your place on the braſen Meridian, and the Quadrant of Altitude to the South Point of the Horizon; which done, turn the Globe with its Furniture till the Quadrant of Altitude comes right againſt the Sun, viz. to his place in the Ecliptic; and keeping it there, ſet the Hour-Index to the XII next the letter *C*; and the Machine will be rectified, not only for the following Problems, but for ſeveral others, which the Artiſt may eaſily find out. To rectify it.

PROBLEM I.

To find the Amplitudes, Meridian Altitudes, and times of riſing, culminating, and ſetting, of the Sun, Moon, and Planets.

Turn the Globe round eaſtward, or according to the order of Signs; and as the eaſtern edge of the Horizon comes right againſt the Sun, Moon, or any Planet, the Hour-Index will ſhew the time of it's riſing; and the inner edge of the Ecliptic will cut it's riſing Amplitude in the Horizon. Turn on, and as the Quadrant of Altitude comes right againſt the Sun, Moon or Planets, the Ecliptic cuts their meridian Altitudes in the Quadrant, and the Hour-Index ſhews the times of their coming to the Meridian. Continue turning, and as the weſtern edge of the Horizon comes right againſt the Sun, Moon, or Planets, their ſetting Amplitudes are cut in the Horizon by the Ecliptic; and the times of their ſetting are ſhewn by the Index on the Hour-Circle. It's uſe.

PROBLEM II.

To find the Altitude and Azimuth of the Sun, Moon, and Planets, at any time of their being above the Horizon.

Turn the Globe till the Index comes to the given time in the Hour-Circle; then keep the Globe ſteady, and moving the Quadrant of Altitude to each Planet reſpectively, the edge of the Ecliptic will cut the Planet's mean Altitude on the Quadrant, and the Quadrant will cut the Planet's Azimuth, or Point of Bearing on the Horizon.

PROBLEM III.

The Sun's Altitude being given at any time either before or after Noon, to find the Hour of the Day, and the Variation of the Compaſs, in any known Latitude.

With one hand hold the edge of the Quadrant right againſt the Sun; and, with the other hand, turn the Globe weſtward, if it be in the forenoon, or eaſtward if it be in the afternoon, until the Sun's place at the inner edge of the Ecliptic cuts the Quadrant in the Sun's obſerved Altitude; and then the Hour-Index will point out the time of the day, and the Quadrant will cut the true Azimuth, or Bearing of the Sun for that time: the difference between which, and the bearing ſhewn by the Azimuth Compaſs, ſhews the Variation of the Compaſs in that place of the Earth.

The TRAJECTORIUM LUNARE.

403. The TRAJECTORIUM LUNARE. This Machine is for delineating the Paths of the Earth and Moon, ſhewing what ſort of Curves they make in the ethereal regions; and was juſt mentioned in the

the 266th Article. *S* is the Sun, and *E* the Earth, whose Centers are 81 Inches distant from each other; every Inch answering to a Million of Miles, § 47. *M* is the Moon, whose Center is $\frac{24}{100}$ parts of an Inch from the Earth's in this Machine, this being in just proportion to the Moon's distance from the Earth, § 52. *AA* is a Bar of Wood, to be moved by hand round the Axis *g* which is fixed in the Wheel *Y*. The Circumference of this Wheel is to the Circumference of the small Wheel *L* (below the other end of the Bar) as $365\frac{1}{4}$ days is to $29\frac{1}{2}$; or as a Year is to a Lunation. The Wheels are grooved round their edges, and in the Grooves is the cat-gut string *GG* crossing between the Wheels at *X*. On the Axis of the Wheel *L* is the Index *F*, in which is fixed the Moon's Axis *M* for carrying her round the Earth *E* (fixed on the Axis of the Wheel *L*) in the time that the Index goes round a Circle of $29\frac{1}{2}$ equal parts, which are the days of the Moon's age. The Wheel *Y* has the Months and Days of the year all round it's Limb; and in the Bar *AA* is fixed the Index *I*, which points out the Days of the Months answering to the Days of the Moon's age, shewn by the Index *F*, in the Circle of $29\frac{1}{2}$ equal parts at the other end of the Bar. On the Axis of the Wheel *L* is put the piece *D*, below the Cock *C*, in which this Axis turns round; and in *D* are put the Pencils *e* and *m*, directly under the Earth *E* and Moon *M*; so that *m* is carried round *e*, as *M* is round *E*. PLATE VII. Fig. V.

Lay the Machine on an even Floor, pressing gently on the Wheel *Y*, to cause it's spiked Feet (of which two appear at *P* and *P*, the third being supposed to be hid from sight by the Wheel) enter a little into the Floor to secure the Wheel from turning. Then lay a paper about four feet long under the Pencils *e* and *m*, cross-wise to the Bar: which done, move the Bar slowly round the Axis *g* of the Wheel *Y*; and, as the Earth *E* goes round the Sun *S*, the Moon *M* will go round the Earth with a duly pro- It's use.

portioned

portioned velocity; and the friction Wheel *W* running on the Floor, will keep the Bar from bearing too heavily on the Pencils *e* and *m*, which will delineate the Paths of the Earth and Moon, as in Fig. 2d, already described at large, § 266, 267. As the Index *I* points out the Days of the Months, the Index *F* shews the Moon's age on these Days, in the Circle of 29½ equal parts. And as this last Index points to the different Days in it's Circle, the like numeral Figures may be set to those parts of the Curves of the Earth's Path and Moon's, where the Pencils *e* and *m* are at those times respectively, to shew the places of the Earth and Moon. If the Pencil *e* be pushed a very little off, as if from the Pencil *m*, to about $\frac{1}{40}$ part of their distance, and the Pencil *m* pushed as much towards *e*, to bring them to the same distances again, though not to the same points of space; then, as *m* goes round *e*, *e* will go as it were round the Center of Gravity between the Earth *e* and Moon *m*, § 298: but this Motion will not sensibly alter the Figure of the Earth's Path or the Moon's.

If a Pin, as *p*, be put through the Pencil *m*, with it's head towards that of the Pin *q* in the Pencil *e*, it's head will always keep thereto as *m* goes round *e*, or as the same side of the Moon is still obverted to the Earth. But the Pin *p*, which may be considered as an equatorial Diameter of the Moon, will turn quite round the Point *m*, making all possible Angles with the Line of it's Progress, or Line of the Moon's Path. This is an ocular proof of the Moon's turning round her Axis.

The TIDE-DIAL. PLATE IX. Fig. VII.

404. The TIDE-DIAL. The outside parts of this Machine consist of, 1. An eight-sided Box, on the top of which at the corners is shewn the Phases of the Moon at the Octants, Quarters, and Full. Within these is a Circle of 29½ equal parts, which are the days of the Moon's age accounted from the Sun at New Moon, round to the Sun again. Within

this Circle is one of 24 hours divided into their respective Halves and Quarters. 2. A moving elliptical Plate, painted blue, to represent the rising of the Tides under and opposite to the Moon; and has the words, *High Water*, *Tide falling*, *Low Water*, *Tide rising*, marked upon it. To one end of this Plate is fixed the Moon *M* by the Wire *W*, and goes along with it. 3. Above this elliptical Plate is a round one, with the Points of the Compass upon it, and also the names of above 200 places in the large Machine (but only 32 in the Figure, to avoid confusion) set over those Points on which the Moon bears when she raises the Tides to the greatest heights at these Places twice in every lunar day: and to the North and South Points of this Plate are fixed two Indexes *I* and *K*, which shew the times of High Water, in the Hour-Circle, at all these places. 4. Below the elliptical Plate are four small Plates, two of which project out from below it's ends at New and Full Moon; and so, by lengthening the Ellipse, shew the Spring Tides, which are then raised to the greatest heights by the united attractions of the Sun and Moon, § 302. The other two of these small Plates appear at low water when the Moon is in her Quadratures, or at the sides of the elliptic Plate, to shew the Neap Tides; the Sun and Moon then acting cross-wise to each other. When any two of these small Plates appear, the other two are hid; and when the Moon is in her Octants, they all disappear, there being neither Spring nor Neap Tides at those times. Within the Box are a few Wheels for performing these Motions by the Handle or Winch *H*.

It's use.

Turn the Handle until the Moon *M* comes to any given day of her age in the Circle of 29½ equal parts, and the Moon's Wire *W* will cut the time of her coming to the Meridian on that day, in the Hour-Circle; the XII under the Sun being Midday, and the opposite XII mid-night: then looking for the name of any given place on the round Plate

(which

(which makes $29\frac{1}{2}$ rotations whilſt the Moon *M* makes only one revolution from the Sun to the Sun again) turn the Handle till *that* place comes to the word *High Water* under the Moon, and the Index which falls among the Forenoon Hours will ſhew the time of High Water at that place in the Forenoon of the given day: then turn the Plate half round, till the ſame place comes to the oppoſite High-Water Mark, and the Index will ſhew the time of High Water in the Afternoon at that place. And thus, as all the different places come ſucceſſively under and oppoſite to the Moon, the Indexes ſhew the times of High Water at them in both parts of the day: and when the ſame places come to the Low-Water Marks, the Indexes ſhew the times of Low Water. For about three days before and after the times of New and Full Moon, the two ſmall Plates come out a little way from below the High-Water Marks on the elliptical Plate, to ſhew that the Tides riſe ſtill higher about theſe times: and about the Quarters, the other two Plates come out a little from under the Low-Water Marks towards the Sun and on the oppoſite ſide, ſhewing that the Tides of Flood riſe not then ſo high, nor do the Tides of Ebb fall ſo low, as at other times.

By pulling the Handle a little way outward, it is diſengaged from the Wheel-work, and then the upper Plate may be turned round quickly by hand ſo, as the Moon may be brought to any given day of her age in about a quarter of a minute: and by puſhing in the Handle, it takes hold of the Wheel-work again.

The inſide work deſcribed.

On *AB*, the Axis of the Handle *H*, is an endleſs Screw *C*, which turns the Wheel *FED* of 24 teeth round in 24 revolutions of the Handle: this Wheel turns another *ONG* of 48 teeth, and on it's Axis is the Pinion *PQ* of four leaves, which turns the Wheel *LKI* of 59 teeth round in $29\frac{1}{2}$ turnings or rotations of the Wheel *FED*, or in 708 revolu-

PLATE XI. Fig. VIII.

tions

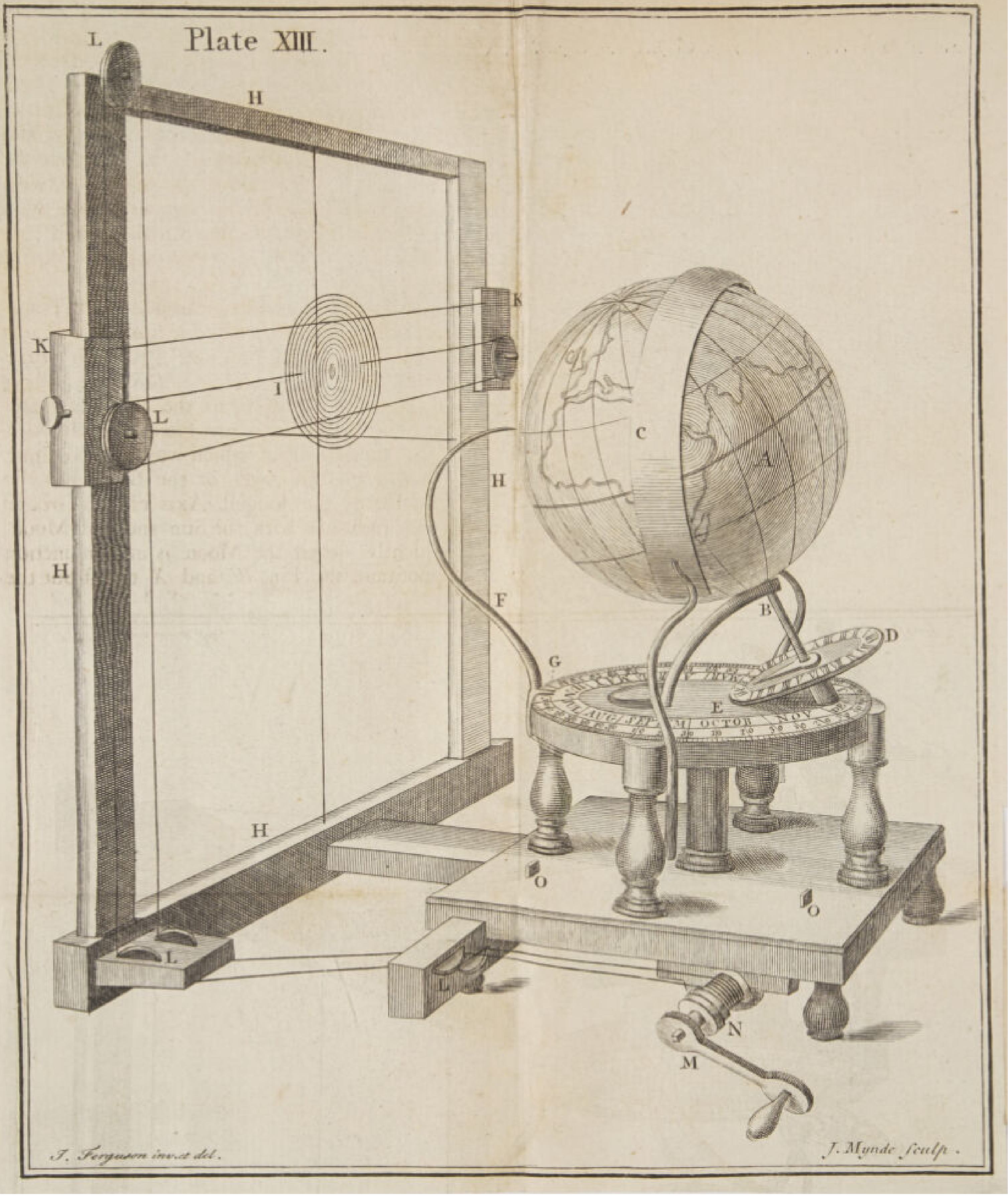
Plate XIII.
L
H
K
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I
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M
J. Ferguson inv. et del.
J. Mynde sculp.

tions of the Handle, which is the number of Hours in a ſynodical revolution of the Moon. The round Plate with the names of Places upon it is fixed on the Axis of the Wheel *FED*; and the Elliptical or Tide-Plate with the Moon fixed to it is upon the Axis of the Wheel *LKI*; conſequently, the former makes 29½ revolutions in the time that the latter makes one. The whole Wheel *FED*, with the endleſs Screw *C*, and dotted part of the Axis of the Handle *AB*, together with the dotted part of the Wheel *ONG*, lie hid below the large Wheel *LKI*.

Fig. IXth repreſents the under ſide of the Elliptical or Tide-Plate *abcd*, with the four ſmall Plates *ABCD*, *EFGH*, *IKLM*, *NOPQ* upon it: each of which has two ſlits, as *TT*, *SS*, *RR*, *UU*, ſliding on two Pins, as *nn* fixed in the elliptical Plate. In the four ſmall Plates are fixed four Pins, at *W*, *X*, *Y*, and *Z*; all of which work in an elliptic Groove *oooo* on the cover of the Box below the elliptical Plate; the longeſt Axis of this Groove being in a right line with the Sun and Full Moon. Conſequently, when the Moon is in Conjunction or Oppoſition, the Pins *W* and *X* thruſt out the Plates *ABCD* and *IKLM* a little beyond the ends of the elliptic Plate at *d* and *b*, to *f* and *e*; whilſt the Pins *Y* and *Z* draw in the Plates *EFGH* and *NOPQ* quite under the elliptic Plate to *g* and *h*. But, when the Moon comes to her firſt or third Quarter, the elliptic Plate lies acroſs the fixed elliptic Groove in which the Pins work; and therefore the end Plates *ABCD* and *IKLM* are drawn in below the great Plate, and the other two Plates *EFGH* and *NOPQ* are thruſt out beyond it to *a* and *c*. When the Moon is in her Octants, the Pins *V*, *X*, *Y*, *Z* are in the parts *o*, *o*, *o*, *o* of the elliptic Groove, which parts are at a mean between the greateſt and leaſt diſtances from the Center *q*, and then all the four ſmall Plates diſappear below the great one.

405. The

The ECLIPSAREON. PL. XIII.

405. The ECLIPSAREON. This Piece of Mechanism exhibits the Time, Quantity, Duration, and Progress of solar Eclipses, at all Parts of the Earth.

The principal parts of this Machine are, 1. A terrestrial Globe *A* turned round it's Axis *B* by the the Handle or Winch *M*; the Axis *B* inclines 23½ Degrees, and has an Index which goes round the Hour-Circle *D* in each rotation of the Globe. 2. A circular Plate *E*, on the Limb of which the Months and Days of the year are inserted. This Plate supports the Globe, and gives it's Axis the same position to the Sun, or to a Candle properly placed, that the Earth's Axis has to the Sun upon any day of the year, § 338, by turning the Plate till the given Day of the Month comes to the fixed Pointer, or Annual-Index *G*. 3. A crooked Wire *F*, which points toward the middle of the Earth's enlightened Disc at all times, and shews to what place of the Earth the Sun is vertical at any given time. 4. A Penumbra, or thin circular Plate of brass *I* divided into 12 Digits by 12 concentric Circles, which represent a Section of the Moon's Penumbra, and is proportioned to the size of the Globe; so that the shadow of this Plate, formed by the Sun, or a Candle placed at a convenient distance, with it's Rays transmitted through a convex Lens to make them fall parallel on the Globe, covers exactly all those places upon it that the Moon's Shadow and Penumbra do on the Earth: so that the Phenomena of any solar Eclipse may be shewn by this Machine with Candle-light almost as well as by the light of the Sun. 5. An upright frame *H H H H*, on the sides of which are Scales of the Moon's Latitude or Declination from the Ecliptic. To these Scales are fitted two Sliders *K* and *K*, with Indexes for adjusting the Penumbra's Center to the Moon's Latitude, as it is North or South Ascending or Descending. 6. A solar Horizon *C*, dividing the enlightened Hemisphere of the

the Globe from that which is in the dark at any given time, and ſhewing at what places the general Eclipſe begins and ends with the riſing or ſetting Sun. 7. A Handle *M*, which turns the Globe round it's Axis by wheel-work, and at the ſame time moves the Penumbra acroſs the frame by threads over the Pulleys *L*, *L*, *L*, with a velocity duly proportioned to that of the Moon's ſhadow over the Earth, as the Earth turns on it's Axis. And as the Moon's Motion is quicker or ſlower, according to her different diſtances from the Earth, the penumbral Motion is eaſily regulated in the Machine by changing one of the Pulleys.

To rectify the Machine for uſe. The true time of New Moon and her Latitude being known by the foregoing Precepts, § 353, *et ſeq.* if her Latitude exceeds the number of minutes or diviſions on the Scales (which are on the ſide of the frame hid from view in the Figure of the Machine) there can be no Eclipſe of the Sun at that Conjunction; but if it does not, the Sun will be eclipſed to ſome places of the Earth; and, to ſhew the times and various appearances of the Eclipſe at thoſe places, proceed in order as follows. To rectify it.

To rectify the Machine for performing by the Light of the Sun. 1. Move the Sliders *K K* till their Indexes point to the Moon's Latitude on the Scales, as it is North or South Aſcending or Deſcending, at that time. 2. Turn the Month-Plate *E* till the day of the given New Moon comes to the Annual-Index *G*. 3. Unſcrew the Collar *N* a little on the Axis of the Handle, to looſen the contiguous Socket on which the threads that move the Penumbra are wound; and ſet the Penumbra by Hand till it's Center comes to the perpendicular thread in the middle of the frame; which thread repreſents the Axis of the Ecliptic. 4. Turn the Handle till the Meridian of *London* on the Globe comes juſt under the point of the crooked Wire *F*; then ſtop, and turn the Hour-Circle *D* by Hand till XII at Noon

comes

comes to it's Index, and set the Penumbra's middle to the thread. 5. Turn the Handle till the Hour-Index points to the time of New Moon in the Circle *D*; and holding it there, screw fast the Collar *N*. Lastly, elevate the Machine till the Sun shines through the Sight-Holes in the small upright Plates *O, O* on the Pedestal; and the whole Machine will be rectified.

To rectify the Machine for shewing by Candle-light. Proceed in every respect as above, except in that part of the last paragraph where the Sun is mentioned; instead of which place a Candle before the Machine, about four yards from it, so as the shadow of Intersection of the cross threads in the middle of the frame may fall precisely on that part of the Globe to which the crooked Wire *F* points: then, with a pair of Compasses, take the distance between the Penumbra's Center and Intersection of the threads; and equal to that distance set the Candle higher or lower, as the Penumbra's Center is above or below the said Intersection. Lastly, place a large convex Lens between the Machine and Candle, so as the Candle may be in the Focus of the Lens, and then the Rays will fall parallel, and cast a strong light on the Globe.

It's use. These things done, which may be sooner than expressed, turn the Handle backward, until the Penumbra almost touches the side *H F* of the frame; then turning it gradually forward, observe the following Phenomena. 1. Where the eastern edge of the Shadow of the penumbral Plate *l* first touches the Globe at the solar Horizon, those who inhabit the corresponding part of the Earth see the Eclipse begin on the uppermost edge of the Sun, just at the time of it's rising. 2. In that place where the Penumbra's Center first touches the Globe, the inhabitants have the Sun rising upon them centrally eclipsed. 3. When the whole Penumbra just falls upon the Globe, it's western edge at the solar Horizon touches and leaves the place where the Eclipse ends

ends at Sun-rise on his lowermost edge. Continue turning, and, 4. the cross lines in the Center of the Penumbra will go over all those places on the Globe where the Sun is centrally eclipsed. 5. When the eastern edge of the Shadow touches any place of the Globe, the Eclipse begins there; when the vertical line in the Penumbra comes to any place, then is the greatest obscuration at that place; and when the western edge of the Penumbra leaves the place, the Eclipse ends there; the times of all which are shewn on the Hour-Circle; and from the beginning to the end, the Shadows of the concentric penumbral Circles shew the numbers of Digits eclipsed at all the intermediate times. 6. When the eastern edge of the Penumbra leaves the Globe at the solar Horizon *C*, the inhabitants see the Sun beginning to be eclipsed on his lowermost edge at it's setting. 7. Where the Penumbra's Center leaves the Globe, the inhabitants see the Sun set centrally eclipsed. And lastly, where the Penumbra is wholly departing from the Globe, the inhabitants see the Eclipse ending on the uppermost part of the Sun's edge, at the time of it's disappearing in the Horizon.

N. B. If any given day of the year on the Plate *E* be set to the Annual-Index *G*, and the Handle turned till the Meridian of any place comes under the point of the crooked Wire, and then the Hour-Circle *D* set by the hand till XII comes to it's Index; in turning the Globe round by the Handle, when the said place touches the eastern edge of the Hoop or solar Horizon *C*, the Index shews the time of Sun-setting at that place; and when the place is just coming out from below the other edge of the Hoop *C*, the Index shews the time when the evening Twilight ends to it. When the place has gone through the dark part *A*, and comes about so as to touch under the back of the Hoop *C*, on the other side, the Index shews the time when the Morning Twilight begins; and when the same place is just coming out from below the edge of the Hoop next the frame, the Index points out the time of Sun-rising. And thus, the times of Sun-rising and setting are shewn at all places in one rotation of the Globe, for any given day of the year: and the point of the crooked Wire *F* shews all the places over which the Sun passes vertically on that day.

A PLAIN

A
PLAIN METHOD

OF FINDING

The DISTANCES of all the PLANETS from the SUN,

BY THE

Transit of VENUS over the SUN's DISC, in the Year 1761.

To which is subjoined,

An Account of Mr. HORROX's Observations of the TRANSIT of VENUS in the Year 1639.

AND ALSO,

Of the DISTANCES of all the PLANETS from the SUN, as deduced from OBSERVATIONS of the TRANSIT in the Year 1761.

Pl. XIV.

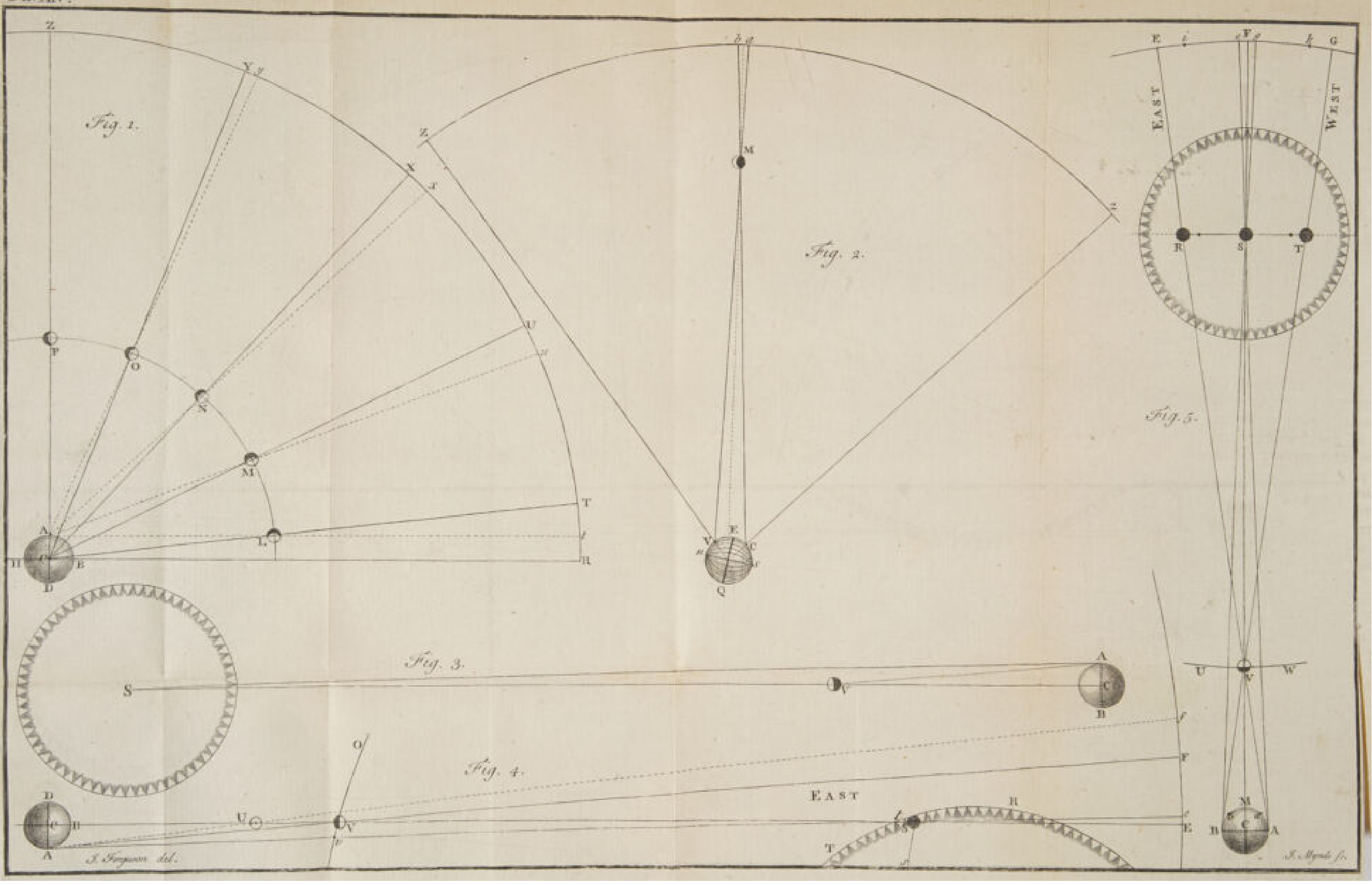


Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
EAST
WEST
EAST
J. Ferguson del.
J. Mynde sc.

THE METHOD OF FINDING The DISTANCES of the PLANETS from the SUN.

CHAPTER XXIII.

ARTICLE I.

Concerning parallaxes, and their uſe in general.

1. THE * approaching tranſit of Venus over the Sun has juſtly engaged the attention of Aſtronomers, as it is a phenomenon ſeldom ſeen, and as the parallaxes of the Sun and planets, and their diſtances from one another, may be found with greater accuracy by it, than by any other method yet known.

2. The parallax of the Sun, Moon, or any planet, is the diſtance between it's true and apparent place in the heaven.—The true place of any celeſtial object, referred to the ſtarry heaven, is that in which it would appear if ſeen from the center of the Earth; the apparent place, is that in which it appears as ſeen from the Earth's ſurface.

To explain this, let *ABDH* be the Earth (Fig. 1. of Plate XIV.) *C* it's center, *M* the Moon, and *ZXR* an arc of the ſtarry heaven. To an obſerver at *C* (ſuppoſing the Earth to be tranſparent) the Moon *M* will appear at *U*, which is her true place

* The whole of this Diſſertation was publiſhed in the beginning of the year 1761, before the time of the Tranſit, except the 7th and 8th Articles, which are added ſince that time.

referred to the ſtarry firmament: but at the ſame inſtant, to an obſerver at *A* ſhe will appear at *u*, below her true place as among the ſtars. The angle *AMC* is called the Moon's parallax, and is equal to the oppoſite angle *UMu*, whoſe meaſure is the celeſtial arc *Uu*.—The whole Earth is but a point if compared with it's diſtance from the fixed ſtars, and therefore we conſider the ſtars as having no parallax at all.

3. The nearer the object is to the horizon, the greater is it's parallax; the nearer it is to the zenith, the leſs. In the horizon it is greateſt of all, in the zenith it is nothing.—Thus let *ALt* be the ſenſible horizon of an obſerver at *A*; to him the Moon at *L* is in the horizon, and her parallax is the angle *ALC*, under which the Earth's ſemidiameter *AC* appears as ſeen from her. This angle is called the Moon's horizontal parallax, and is equal to the oppoſite angle *TLt*, whoſe meaſure is the arc *Tt* in the ſtarry heaven. As the Moon riſes higher and higher to the points *M*, *N*, *O*, *P* in her diurnal courſe, the parallactic angles *UMu*, *XNx*, *YOy* diminiſh, and ſo do the arcs *Uu*, *Xx*, *Yy*, which are their meaſures, until the Moon comes to *P*; and then ſhe appears in the zenith *Z* without any parallax, her place being the ſame as ſeen from *A* on the Earth's ſurface, and from *C* it's center.

4. If the obſerver at *A* could take the true meaſure or quantity of the parallactic angle *ALC*, he might thereby find the Moon's diſtance from the center of the Earth. For then, in the plain triangle *LAC*, the ſide *AC*, which is the Earth's ſemidiameter, the angle *ALC*, which is the Moon's horizontal parallax, and the right angle *CAL*, would be given. Therefore, by trigonometry, As the tangent of the parallactic angle *ALC* is to radius, ſo is the Earth's ſemidiameter *AC* to the Moon's diſtance *CL* from the Earth's center *C*.—But becauſe we conſider the Earth's ſemidiameter as unity, and the logarithm of unity is nothing, ſub-

tract the logarithmic tangent of the angle ALC from radius, and the remainder will be the logarithm of CL, whose number is equal to the number of semidiameters of the Earth by which the Moon is distant from the Earth's center.—Thus supposing the angle ALC of the Moon's horizontal parallax to be 57′ 18″.

From the radius — — —	10.0000000
Subtract the tangent of 57′ 18″	8.2219207
And there will remain — —	1.7780793;

which is the logarithm of 59.9955, the number of semidiameters of the Earth which are equal to the Moon's distance from the Earth's center. Then, 59.9955 being multiplied by 3985, the number of miles contained in the Earth's semidiameter, will give 239,082 miles for the Moon's distance from the center of the Earth.

5. But the true quantity of the Moon's horizontal parallax cannot be accurately determined by observing the Moon in the horizon, on account of the inconstancy of the horizontal refractions, which always vary according to the state of the atmosphere; and, at a mean rate, elevate the Moon's apparent place near the horizon half as much more than as her parallax depresseth it. And therefore, to have her parallax more accurate, Astronomers have thought of the following method, which seems to be a very good one, but hath not yet been put in practice.

Let two observers be placed under the same meridian, one in the northern hemisphere, and the other in the southern, at such a distance from each other, that the arc of the celestial meridian included between their two zeniths may be at least 80 or 90 degrees. Let each observer take the distance of the Moon's center from his zenith, by means of an exceeding good instrument, at the moment of her passing the meridian: add these two zenith-distances of the Moon together, and their excess above the distance between the two zeniths will be the distance between the two apparent places of the Moon. Then, as the sum of the natural sines of the two zenith-distances of the Moon is to radius, so is the distance between her two apparent places to her horizontal parallax: which being found, her distance from the Earth's center may be found by the analogy mentioned in § 4.

Thus, in Fig. 2. let *V E C Q* be the Earth, *M* the Moon, and *Z b a z* an arc of the celestial meridian. Let *V* be *Vienna*, whose latitude *E V* is 48° 20′ north; and *C* the *Cape of Good Hope*, whose latitude *E C* is 34° 30′ south: both which latitudes we suppose to be accurately determined before-hand by the observers. As these two places are on the same meridian *n V E C s*, and in different hemispheres, the sum of their latitudes 82° 50′ is their distance from each other. *Z* is the zenith of *Vienna*, and *z* the zenith of the *Cape of Good Hope*; which two zeniths are also 82° 50′ distant from each other, in the common celestial meridian *Z z*. To the observer at *Vienna*, the Moon's center will appear at *a* in the celestial meridian; and at the same instant, to the observer at the *Cape*, it will appear at *b*. Now suppose the Moon's distance *Z a* from the zenith of *Vienna* to be 38° 1′ 53″; and her distance *z b* from the zenith of the *Cape of Good Hope* to be 46° 4′ 41″: the sum of these two zenith-distances ($Za + zb$) is 84° 6′ 34″, from which subtract 82° 50″, the distance *Z z* between the zeniths of these two places, and there will remain 1° 16′ 34″ for the arc *b a*, or distance between the two apparent places of the Moon's center, as seen from *V* and from *C*. Then, supposing the tabular radius to be 10000000, the natural sine of 38° 1′ 53″ (the arc *Z a*) is 6160816, and the natural sine of 46° 4′ 41″ (the arc *z b*) is 7202821: the sum of both these sines is 13363637. Say therefore, As 13363637

7 hours and 3 quarters. But Venus's orbit (like the Moon's) only interfects the ecliptic in two oppofite points, called it's Nodes. And therefore one half of it is on the north fide of the ecliptic, and the other on the fouth: on which account, Venus can never be feen on the Sun, but at thofe inferior conjunctions which happen in or near the nodes of her orbit. At all the other conjunctions, fhe either paffes above or below the Sun; and her dark fide being then towards the Earth, fhe is invifible. —The laft time when this planet was feen like a fpot on the Sun, was on the 24th of *November* Old Stile, in the year 1639.

ARTICLE II.

Shewing how to find the horizontal parallax of Venus by obfervation, and from thence, by analogy, the parallax and diftance of the Sun, and of all the Planets from him.

9. In Fig. 4. of Plate XIV. let DBA be the Earth, V Venus, and TSR the eaftern limb of the Sun. To an obferver at B, the point t of that limb will be on the meridian, it's place referred to the heaven will be at E, and Venus will appear juft within it at S. But, at the fame inftant, to an obferver at A, Venus is eaft of the Sun, in the right line AVF; the point t of the Sun's limb appears at e in the heaven, and if Venus were then vifible, fhe would appear at F. The angle CVA is the horizontal parallax of Venus, which we feek; and is equal to the oppofite angle FVE, whofe meafure is the arc FE. ASC is the Sun's horizontal parallax, equal to the oppofite angle eSE, whofe meafure is the arc eE: and FAe (the fame as VAv) is Venus's horizontal parallax from the Sun, which may be found by obferving how much later in abfolute time her total ingrefs on the Sun is, as feen from A, than as feen from B, which is the time

time ſhe takes to move from V to v in her orbit OVv.

10. It appears by the tables of Venus's motion and the Sun's, that at the time of her enſuing tranſit, ſhe will move 4′ of a degree on the Sun's diſc in 60 minutes of time; and therefore ſhe will move 4″ of a degree in one minute of time.

Now, let us ſuppoſe, that A is 90° weſt of B, ſo that when it is noon at B, it will be VI in the morning at A; that the total ingreſs as ſeen from B is at 1 minute paſt XII. but that as ſeen from A it is at 7 minutes 30 ſeconds paſt VI: deduct 6 hours for the difference of meridians of A and B, and the remainder will be 6 minutes 30 ſeconds for the time by which the total ingreſs of Venus on the Sun at S is later as ſeen from A than as ſeen from B: which time being converted into parts of a degree is 26″, or the arc Fe of Venus's horizontal parallax from the Sun: for, as 1 minute of time is to 4 ſeconds of a degree, ſo is $6\frac{1}{2}$ minutes of time to 26 ſeconds of a degree.

11. The times in which the planets perform their annual revolutions about the Sun, are already known by obſervation.—From theſe times, and the univerſal power of gravity by which the planets are retained in their orbits, it is demonſtrable, that if the Earth's mean diſtance from the Sun be divided into 100000 equal parts, Mercury's mean diſtance from the Sun muſt be equal to 38710 of theſe parts—Venus's mean diſtance from the Sun, to 72333—Mars's mean diſtance, 152369—Jupiter's 520096—and Saturn's, 954006. Therefore, when the number of miles contained in the mean diſtance of any planet from the Sun is known, we we can, by theſe proportions, find the mean diſtance in miles of all the reſt.

12. At the time of the enſuing tranſit, the Earth's diſtance from the Sun will be 1015 (the mean diſtance being here conſidered as 1000) and Venus's diſtance from the Sun will be 726 (the mean

mean diſtance being conſidered as 723) which differences from the mean diſtances ariſe from the elliptical figure of the planets orbits.—Subtract 726 parts from 1015, and there will remain 289 parts for Venus's diſtance from the Earth at that time.

13. Now, ſince the horizontal parallaxes of the planets are * inverſely as their diſtances from the Earth's center, it is plain, that as Venus will be between the Earth and the Sun on the day of her tranſit, and conſequently her parallax will be then greater than the Sun's, if her horizontal parallax can be then aſcertained by obſervation, the Sun's horizontal parallax may be found, and conſequently his diſtance from the Earth.—Thus, ſuppoſe Venus's horizontal parallax ſhould be found to be 36″.3480; then, As the Sun's diſtance 1015 is to Venus's diſtance 289, ſo is Venus's horizontal parallax 36″.3480 to the Sun's horizontal parallax 10″.3493 on the day of her tranſit. And the difference of theſe two parallaxes, viz. 25″.9987 (which may be eſteemed 26″) will be the quantity of Venus's horizontal parallax from the Sun; which is one of the elements for projecting or delineating her tranſit over the Sun's diſc, as will appear further on.

To find the Sun's horizontal parallax at the time of his mean diſtance from the Earth, ſay, As 1000 parts, the Sun's mean diſtance from the Earth's center, is to 1015, his diſtance therefrom on the

* To prove this, let *S* be the Sun (Fig. 3.) *V* Venus, *A B* the Earth, *C* it's center, and *A C* it's ſemidiameter. The angle *A V C* is the horizontal parallax of Venus, and *A S C* the horizontal parallax of the Sun. But by the property of plain triangles, as the ſine of *A V C* (or of *S V A* it's ſuppliment to 180°) is to the ſine of *A S C*, ſo is *A S* to *A V*, and ſo is *C S* to *C V*.—*N. B.* In all angles leſs than a minute of a degree, the ſines, tangents, and arcs, are ſo nearly equal, that they may without error be uſed for one another. And here we make uſe of *Gardiner's* logarithmic tables, becauſe they have the ſines to every ſecond of a degree.

day

day of the tranſit, ſo is 10″.3493, his horizontal parallax on that day, to 10″.5045, his horizontal parallax at the time of his mean diſtance from the Earth's center.

14. The Sun's parallax being thus (or any other way ſuppoſed to be) found, at the time of his mean diſtance from the Earth, we may find his true diſtance therefrom, in ſemidiameters of the Earth, by the following analogy. As the ſine (or tangent of ſo ſmall an arc as that) of the Sun's parallax 10″.5045 is to radius, ſo is unity or the Earth's ſemidiameter to the number of ſemidiameters of the Earth that the Sun is diſtant from it's center, which number, being multiplied by 3985, the number of miles contained in the Earth's ſemidiameter, will give the number of miles by which the Sun is diſtant from the Earth's center.

Then, by § 11, As 100000, the Earth's mean diſtance from the Sun in parts, is to 38710, Mercury's mean diſtance from the Sun in parts, ſo is the Earth's mean diſtance from the Sun in miles to Mercury's mean diſtance from the Sun in miles.—And,

As 100000 is to 72333, ſo is the Earth's mean diſtance from the Sun in miles to Venus's mean diſtance from the Sun in miles.—Likewiſe,

As 100000 is to 152369, ſo is the Earth's mean diſtance from the Sun in miles to Mars's mean diſtance from the Sun in miles.—Again,

As 100000 is to 520096, ſo is the Earth's mean diſtance from the Sun in miles to Jupiter's mean diſtance from the Sun in miles.—Laſtly,

As 100000 is to 954006, ſo is the Earth's mean diſtance from the Sun in miles to Saturn's mean diſtance from the Sun in miles.

And thus, by having found the diſtance of any one of the planets from the Sun, we have ſufficient *data* for finding the diſtances of all the reſt.—And then, from their apparent diameters at theſe known diſtances,

distances, their real diameters and bulks may be found.

15. The Earth's diameter, as seen from the Sun, subtends an angle of double the Sun's horizontal parallax, at the time of the Earth's mean distance from the Sun: and the Sun's diameter, as seen from the Earth at that time, subtends an angle of $32' 2''$, or $1922''$. Therefore, the Sun's diameter is to the Earth's diameter, as 1922 is to 21.—And since the relative bulks of spherical bodies are as the cubes of their diameters, the Sun's bulk is to the Earth's bulk, as 756058 is to 1; supposing the Sun's mean horizontal parallax to be $10''.50$, as above.

16. It is plain by Fig. 4. that whether Venus be at *U* or *V*, or in any other part of the right line *BVS*, it will make no difference in the time of her total ingress on the Sun at *S*, as seen from *B*; but as seen from *A* it will. For, if Venus be at *V*, her horizontal parallax from the Sun is the arc *Fe*, which measures the angle *FAe*: but if she be nearer the Earth, as at *U*, her horizontal parallax from the Sun is the arc *fe*, which measures the angle *fAe*; and this angle is greater than the angle *FAe*, by the difference of their measures *fF*. So that, as the distance of the celestial object from the Earth is less, it's parallax is the greater.

17. To find the parallax of Venus by the above method, it is necessary, 1. That the difference of meridians of the two places of observation be 90°.—2. That the time of Venus's total ingress on the Sun be when his eastern limb is either on the meridian of one of the places, or very near it.—And, 3. That each observer has his clock exactly regulated to the equal time at his place. But as it might perhaps be difficult to find two places on the Earth suited to the first and second of these requisites, we shall shew how this important problem may be solved by a single observer, if he be exact

as

as to his longitude, and has his clock truly adjuſted to the equal time at his place.

18. That part of Venus's orbit in which ſhe will move during her tranſit on the Sun, may be conſidered as a ſtraight line; and therefore, a plane may be conceived to paſs both through it and the Earth's center. To every place on the Earth's ſurface cut by this plane, Venus will be ſeen on the Sun in the ſame path that ſhe would deſcribe as ſeen from the Earth's center: and therefore, ſhe will have no parallax of latitude, either north or ſouth; but will have a greater or leſs parallax of longitude, as ſhe is more or leſs diſtant from the meridian, at any time during her tranſit.

Matura, a town and fort on the ſouth coaſt of the iſland of *Ceylon*, will be in this plane at the time of Venus's total ingreſs on the Sun; and the Sun will then be 62°$\frac{1}{2}$ eaſt of the meridian of that place. Conſequently, to an obſerver at *Matura*, Venus will have a conſiderable parallax of longitude eaſtward from the Sun, when ſhe would appear to touch the Sun's eaſtern limb, as ſeen from the Earth's center, at which the Aſtronomical tables ſuppoſe the obſerver to be placed, and give the times as ſeen from thence.

19. According to theſe tables, Venus's total ingreſs on the Sun will be 50 minutes after VII in the morning, at *Matura* *, ſuppoſing that place to be 80° eaſt longitude from the meridian of *London*; which is the obſerver's buſineſs to determine. Let us imagine that he finds it to be exactly ſo, but that to him the total ingreſs is at VII hours 55 minutes 46 ſeconds, which is 5 minutes 46 ſeconds later than the true calculated time of total ingreſs, as ſeen from the Earth's center. Then, as Venus's

* The time of total ingreſs at *London*, as ſeen from the Earth's center, is at 30 minutes after II in the morning; and if *Matura* be juſt 80° (or 5 hours 20 minutes) eaſt of *London*, when it is 30 minutes paſt II in the morning at *London*, it is 50 minutes paſt VII at *Matura*.

motion

motion on (or towards, or from) the Sun is at the rate of 4 minutes of a degree in an hour (by § 10.) her motion must be 23″.1 of a degree in 5 minutes 46 seconds of time: and this 23″.1 is her parallax eastward, from her total ingress as seen from *Matura*, when her ingress would be total if seen from the Earth's center.

20. At VII hours 50 minutes in the morning, the Sun is 62°½ from the meridian; at VI in the morning he is 90° from it: therefore, as the sine of 62°½ is to the sine of 23″.1 (which is Venus's parallax from her true place on the Sun at VII hours 50 minutes) so is radius, or the sine of 90°, to the sine of 26″, which is Venus's horizontal parallax from the Sun at VI. In logarithms thus:

As the logarithmic sine of 62° 30′ - - -	9.9479289
Is to the logarithmic sine of 23″.1 - - -	6.0481510
So is the logarithmic radius - - - - - - -	10.0000000
To the logarithmic sine of 26″ very nearly	6.1002221

Divide the Sun's distance from the Earth, 1015, by his distance from Venus 726 (§ 12.) and the quotient will be 1.3980; which being multiplied by Venus's horizontal parallax from the Sun 26″. will give 36″.3480 for her horizontal parallax as seen from the Earth at that time.—Then (by § 13.) As the Sun's distance 1015 is to Venus's distance 289, so is Venus's horizontal parallax 36″.3480 to the Sun's horizontal parallax 10″.3493.—If Venus's horizontal parallax from the Sun is found by observation to be greater or less than 26″, the Sun's horizontal parallax must be greater or less than 10″.3493 accordingly.

21. And thus, by a single observation, the parallax of Venus, and consequently the parallax of the Sun, might be found, if we were sure that the Astronomical tables were quite correct as to the time of Venus's total ingress on the Sun.—But although the tables may be safely depended upon

for

for ſhewing the true duration of the tranſit, which will not be quite 6 hours from the time of Venus's total ingreſs on the Sun's eaſtern limb, to the beginning of her egreſs from his weſtern; yet they may perhaps not give the true times of theſe two internal contacts: like a good common clock, which though it may be truſted to for meaſuring a few hours of time, yet perhaps it may not be quite adjuſted to the meridian of the place, and conſequently not true as to any one hour; which every one knows is generally the caſe.—Therefore, to make ſure work, the obſerver ought to watch both the moment of Venus's total ingreſs on the Sun, and her beginning of egreſs from him, ſo as to note preciſely the time between theſe two inſtants, by means of a good clock: and by comparing the interval at his place with the true calculated interval as ſeen from the Earth's center, which will be 5 hours 58 minutes, he may find the parallax of Venus from the Sun both at her total ingreſs and beginning of egreſs.

22. The manner of obſerving the tranſit ſhould be as follows.—The obſerver being provided with a good teleſcope, and a pendulum clock well adjuſted to the mean diurnal revolution of the Sun, and as near to the time at his place as conveniently may be; and having an aſſiſtant to watch the clock at the proper times, he muſt begin to obſerve the Sun's eaſtern limb through his teleſcope, twenty minutes at leaſt before the computed time of Venus's total ingreſs upon it, leſt there ſhould be an error in the time thereof as given by the tables.

When he perceives a dent (as it were) to be made in the Sun's limb by the interpoſition of the dark body of Venus, he muſt then continue to watch her through the teleſcope as the dent increaſes; and his aſſiſtant muſt watch the time ſhewn by the clock, till the whole body of the planet appears juſt within the Sun's limb: and the moment when the bright limb of the Sun appears cloſe by the eaſt ſide of the dark limb of the planet, the obſerver, having a little hammer in his hand, is to ſtrike a blow therewith on the table or wall; the moment of which, the aſſiſtant notes by the clock, and writes it down.

Then, let the planet paſs on for about 2 hours 59 minutes, in which time it will be got to the middle of it's apparent path on the Sun, and conſequently will then be at it's leaſt apparent diſtance from the Sun's center; at which time, the obſerver muſt take it's diſtance from the Sun's center, by means of a good micrometer, in order to aſcertain it's true latitude or declination from the ecliptic, and thereby find the places of it's nodes.

This done, there is but little occaſion to obſerve it any longer, until it comes ſo near the Sun's weſtern limb, as almoſt to touch it. Then the obſerver watches the planet carefully with his teleſcope; and his aſſiſtant watches the clock, ſo as to note the preciſe moment of the planet's touching the Sun's limb, which the aſſiſtant knows by the obſerver's ſtriking a blow with his hammer.

23. The aſſiſtant muſt be very careful in obſerving what minute on the Dial-Plate the minute-hand has paſt, when he has obſerved the ſecond-hand at the inſtant the blow was ſtruck by the hammer: otherwiſe, though he be right as to the number of ſeconds of the current minute, he may be apt to make a miſtake in the number of minutes.

24. To thoſe places where the tranſit begins before XII at noon, and ends after it, Venus will have an eaſtern parallax from the Sun at the beginning, and a weſtern parallax from the Sun at the end; which will contract the duration of the tranſit, by cauſing it to begin later, and end ſooner at theſe places, than it does as ſeen from the Earth's center; which may be explained in the following manner.

In

In Fig. 5. of Plate XIV. let *BMA* be the Earth, *V* Venus, and *S* the Sun. The Earth's motion on it's axis from weſt to eaſt, or in the direction *AMB*, carries an obſerver on that ſide contrary to the motion of Venus in her orbit, which is in the direction *UVW*, and will therefore cauſe her motion to appear quicker on the Sun's diſc, than it would appear to an obſerver placed at the Earth's center *C*, or at either of it's poles. For, if Venus were to ſtand ſtill in her orbit at *V* for twelve hours, the obſerver on the Earth's ſurface would in that time be carried from *A* to *B*, through the arc *AMB*. When he was at *A*, he would ſee Venus on the Sun at *R*; when at *M*, he would ſee her at *S*; and when he was at *B*, he would ſee her at *T*: ſo that his own motion would cauſe the planet to appear in motion on the Sun through the line *RST*: which being in the direction of her apparent motion on the Sun as ſhe moves in her orbit *UW*, her motion will be accelerated on the Sun to this obſerver, juſt as much as his own motion would ſhift her apparent place on the Sun, if ſhe were at reſt in her orbit at *V*.

But as the whole duration of the tranſit, from firſt to laſt internal contact, will not be quite ſix hours; an obſerver, who has the Sun on his meridian at the middle of the tranſit, will be carried only from *a* to *b* during the whole time thereof. And therefore, the duration will be much leſs contracted by his own motion, than if the planet were to be twelve hours in paſſing over the Sun, as ſeen from the Earth's center.

25. The nearer Venus is to the Earth, the greater is her parallax, and the more will the true duration of her tranſit be contracted thereby; the farther ſhe is from the Earth, the contrary: ſo that the contraction will be in direct proportion to the parallax. Therefore, by obſerving, at proper places, how much the duration of the tranſit is leſs than it's true duration at the Earth's center, where it is

5 hours 58 minutes, as given by the Aſtronomical tables, the parallax of Venus will be aſcertained.

26. The above method (§ 17, *& ſeq.*) is much the ſame as was preſcribed long ago by Doctor HALLEY, but the calculations differ conſiderably from his; as will appear in the next article, which contains a tranſlation of the Doctor's whole diſſertation on that ſubject.—He had not computed his own tables when he wrote it, nor had he time before-hand to make a ſufficient number of obſervations on the motion of Venus, ſo as to determine whether the nodes of her orbit are at reſt or no; and was therefore obliged to truſt to other tables, which are now found to be erroneous.

ARTICLE III.

Containing Doctor HALLEY's *Diſſertation on the method of finding the Sun's parallax and diſtance from the Earth, by the tranſit of Venus over the Sun's Diſc,* June *the 6th,* 1761. *Tranſlated from the Latin in* Motte's *Abridgment of the Philoſophical Tranſactions, Vol. I. pag.* 243; *with additional notes.*

There are many things exceedingly paradoxical, and that ſeem quite incredible to the illiterate, which yet by means of mathematical principles may be eaſily ſolved. Scarce any problem will appear more hard and difficult, than that of determining the diſtance of the Sun from the Earth very near the truth: but even this, when we are made acquainted with ſome exact obſervations, taken at places fixed upon, and choſen before-hand, will without much labour be effected. And this is what I am now deſirous to lay before this illuſtrious Society * (which I foretell will continue for ages) that I may explain before-hand to young Aſtronomers, who may perhaps live to obſerve

* The Royal Society.

theſe

theſe things, the method whereby the immenſe diſtance of the Sun may be truly obtained, to within a five hundredth part of what it really is.

It is well known that the diſtance of the Sun from the Earth is by different Aſtronomers ſuppoſed different, according to what was judged moſt probable from the beſt conjecture that each could form. *Ptolemy* and his followers, as alſo *Copernicus* and *Tycho Brahe*, thought it to be 1200 ſemidiameters of the Earth: *Kepler* 3500 nearly; *Ricciolus* doubles the diſtance mentioned by *Kepler*, and *Hevelius* only increaſes it by one half. But the planets Venus and Mercury having, by the aſſiſtance of the teleſcope, been ſeen in the diſc of the Sun, deprived of their borrowed brightneſs, it is at length found, that the apparent diameter of the planets are much leſs than they were formerly ſuppoſed; and that the ſemidiameter of Venus ſeen from the Sun ſubtends no more than a fourth part of a minute, or fifteen ſeconds, whilſt the ſemidiameter of Mercury, at it's mean diſtance from the Sun, is ſeen under an angle only of ten ſeconds; that the ſemidiameter of Saturn ſeen from the Sun appears under the ſame angle; and that the ſemidiameter of Jupiter, the largeſt of all the planets, ſubtends an angle of no more than a third part of a minute at the Sun. Whence, keeping the proportion, ſome modern Aſtronomers have thought, that the ſemidiameter of the Earth, ſeen from the Sun, would ſubtend a mean angle between that larger one ſubtended by Jupiter, and that ſmaller one ſubtended by Saturn and Mercury; and equal to that ſubtended by Venus, (namely, fifteen ſeconds:) and have thence concluded, that the Sun is diſtant from the Earth almoſt 14000 of the Earth's ſemidiameters. But the ſame authors have on another account ſomewhat increaſed this diſtance: for, inaſmuch as the Moon's diameter is a little more than a fourth part of the diameter of the Earth, if the Sun's parallax ſhould be ſuppoſed fifteen ſeconds, it would follow, that the body of the Moon is larger than that of Mercury; that is, that a ſecondary planet would be greater than a primary, which would ſeem inconſiſtent with the uniformity of the mundane ſyſtem. And on the contrary, the ſame regularity and uniformity ſeems ſcarcely to admit, that Venus, an inferior planet, that has no ſatellite, ſhould be greater than our Earth, which ſtands higher in the ſyſtem, and has ſuch a ſplendid attendant. Therefore, to obſerve a mean, let us ſuppoſe the ſemidiameter of the Earth ſeen from the Sun, or, which is the ſame thing, the Sun's horizontal parallax, to be twelve ſeconds and a half; according to which, the Moon will be leſs than Mercury, and the Earth larger than Venus; and the Sun's diſtance from the Earth will come out nearly 16500 of the Earth's ſemidiameters. This diſtance I aſſent to at preſent, as the true one, till it ſhall become certain what it is, by the experiment which I propoſe. Nor am I induced to alter my opinion by the authority of thoſe (however weighty it may be) who are for placing the Sun at an immenſe diſtance beyond the bounds here aſſigned, relying on obſervations made upon the vibrations of a pendulum, in order to determine thoſe exceeding ſmall angles; but which, as it ſeems, are not ſufficient to be depended upon: at leaſt, by this method of inveſtigating the parallax, it will come out ſometimes nothing, or even negative; that is, the diſtance would either become infinite, or greater than infinite; which is abſurd. And indeed, to confeſs the truth, it is hardly poſſible for a man to diſtinguiſh, with any degree of certainty, ſeconds, or even ten ſeconds, with inſtruments, let them be ever ſo ſkilfully made: therefore, it is not at all to be wondered at, that the exceſſive nicety of this matter has eluded the many and ingenious endeavours of ſuch ſkilful operators.

About forty years ago, whilſt I was in the iſland of *St. Helena*, obſerving the ſtars about the ſouth pole,

pole, I had an opportunity of obſerving, with the greateſt diligence, Mercury paſſing over the diſc of the Sun; and (which ſucceeded better than I could have hoped for) I obſerved, with the greateſt degree of accuracy, by means of a teleſcope 24 feet long, the very moment when Mercury entering upon the Sun ſeemed to touch it's limb within, and alſo the moment when going off it ſtruck the limb of the Sun's diſc, forming the angle of interior contact: whence I found the interval of time, during which Mercury then appeared within the Sun's diſc, even without an error of one ſecond of time. For the lucid line intercepted between the dark limb of the planet and the bright limb of the Sun, although exceeding fine, is ſeen by the eye; and the little dent made in the Sun's limb, by Mercury's entering the diſc, appears to vaniſh in a moment; and alſo that made by Mercury, when leaving the diſc, ſeems to begin in an inſtant.—When I perceived this, it immediately came into my mind, that the Sun's parallax might be accurately determined by ſuch kind of obſervations as theſe; provided Mercury were but nearer to the Earth, and had a greater parallax from the Sun: but the difference of theſe parallaxes is ſo little, as always to be leſs than the ſolar parallax which we ſeek; and therefore Mercury, though frequently to be ſeen on the Sun, is not to be looked upon as fit for our purpoſe.

There remains then the tranſit of Venus over the Sun's diſc; whoſe parallax, being almoſt four times as great as the ſolar parallax, will cauſe very ſenſible differences between the times in which Venus will ſeem to be paſſing over the Sun at different parts of the Earth. And from theſe differences, if they be obſerved as they ought, the Sun's parallax may be determined even to a ſmall part of a ſecond. Nor do we require any other inſtruments for this purpoſe, than common teleſcopes and clocks, only good of their kind; and in the obſervers, nothing more is needful than fidelity, diligence, and a moderate ſkill in Aſtronomy.

For there is no need that the latitude of the place ſhould be ſcrupulouſly obſerved, nor that the hours themſelves ſhould be accurately determined with reſpect to the meridian: it is ſufficient that the clocks be regulated according to the motion of the heavens, if the times be well reckoned from the total ingreſs of Venus into the Sun's diſc, to the beginning of her egreſs from it; that is, when the dark globe of Venus firſt begins to touch the bright limb of the Sun within; which moments, I know by my own experience, may be obſerved within a ſecond of time.

But on account of the very ſtrict laws by which the motions of the planets are regulated, Venus is ſeldom ſeen within the Sun's diſc: and during the courſe of more than 120 years, it could not be ſeen once; namely, from the year 1639 (when this moſt pleaſing ſight happened to that excellent youth *Horrax* our countryman, and to him only, ſince the creation) to the year 1761; in which year, according to the theories which we have hitherto found agreeable to the celeſtial motions, Venus will again paſs over the Sun on the * 26th of *May*, in the morning; ſo that at *London*, about ſix o'clock in the morning, we may expect to ſee it near the middle of the Sun's diſc, and not above four minutes of a degree ſouth of the Sun's center. But the duration of this tranſit will be almoſt eight hours; namely, from two o'clock in the morning till almoſt ten. Hence the ingreſs will not be viſible in *England*; but as the Sun will at that time be in the 16th degree of Gemini, having almoſt 23 degrees north declination, it will be ſeen without ſetting at all in almoſt all parts of the north frigid zone: and therefore the inhabitants of the coaſt of *Norway*, beyond the city of *Nidroſia*, which is called *Drontheim*, as far as the *North Cape*, will be able to obſerve Venus entering the Sun's diſc; and perhaps the ingreſs of Venus upon

* The ſixth of *June* according to the New Stile.

the

the Sun, when rising, will be seen by the *Scotch*, in the northern parts of the kingdom, and by the inhabitants of the *Shetland Isles*, formerly called *Thule*. But at the time when Venus will be nearest the Sun's center, the Sun will be vertical to the northern shores of the bay of *Bengal*, or rather over the kingdom of *Pegu*; and therefore, in the adjacent regions, as the Sun, when Venus enters his disc, will be almost four hours toward the east, and as many to the west when she leaves him, the apparent motion of Venus on the Sun will be accelerated by almost double the horizontal parallax of Venus from the Sun; because Venus at that time is carried with a retrograde motion from east to west, whilst an eye placed upon the Earth's surface is whirled the contrary way, from west to east *.

Supposing

* This has been already taken notice of in § 24; but I shall here endeavour to explain it more at large, together with some of the following part of the Doctor's Essay, by a figure.

In Fig. 1. of Plate XV. let C be the center of the Earth, and Z the center of the Sun. In the right line $C v Z$, make $v Z$ to $C Z$ as 726 is to 1015 (§ 12.) Let $a c b d$ be the Earth, v Venus's place in her orbit at the time of her conjuction with the Sun; and let $T S U$ be the Sun, whose diameter is $31' \, 42''$.

The motion of Venus in her orbit is in the direction $N v n$, and the Earth's motion on it's axis is according to the order of the 24 hours placed around it in the figure. Therefore, supposing the mouth of the *Ganges* to be at G, when Venus is at E in her orbit, and to be carried from G to g by the Earth's motion on it's axis, whilst Venus moves from E to e in her orbit; it is plain, that the motions of Venus and the *Ganges* are contrary to each other.

The true motion of Venus in her orbit, and consequently the space she seems to run over on the Sun's disc in any given time, could be seen only from the Earth's center C, which is at rest with respect to it's surface. And as seen from C, her path on the Sun would be in the right line $T t U$; and her motion therein at the rate of four minutes of a degree in an hour. T is the point of the Sun's eastern limb which Venus seems to touch at the moment of her total ingress on the Sun, as seen from C, when Venus is at E in her orbit; and U is the point of the Sun's western limb which she seems to touch at the moment of her beginning of egress from the Sun, as seen from C, when she is at e in her orbit.

When

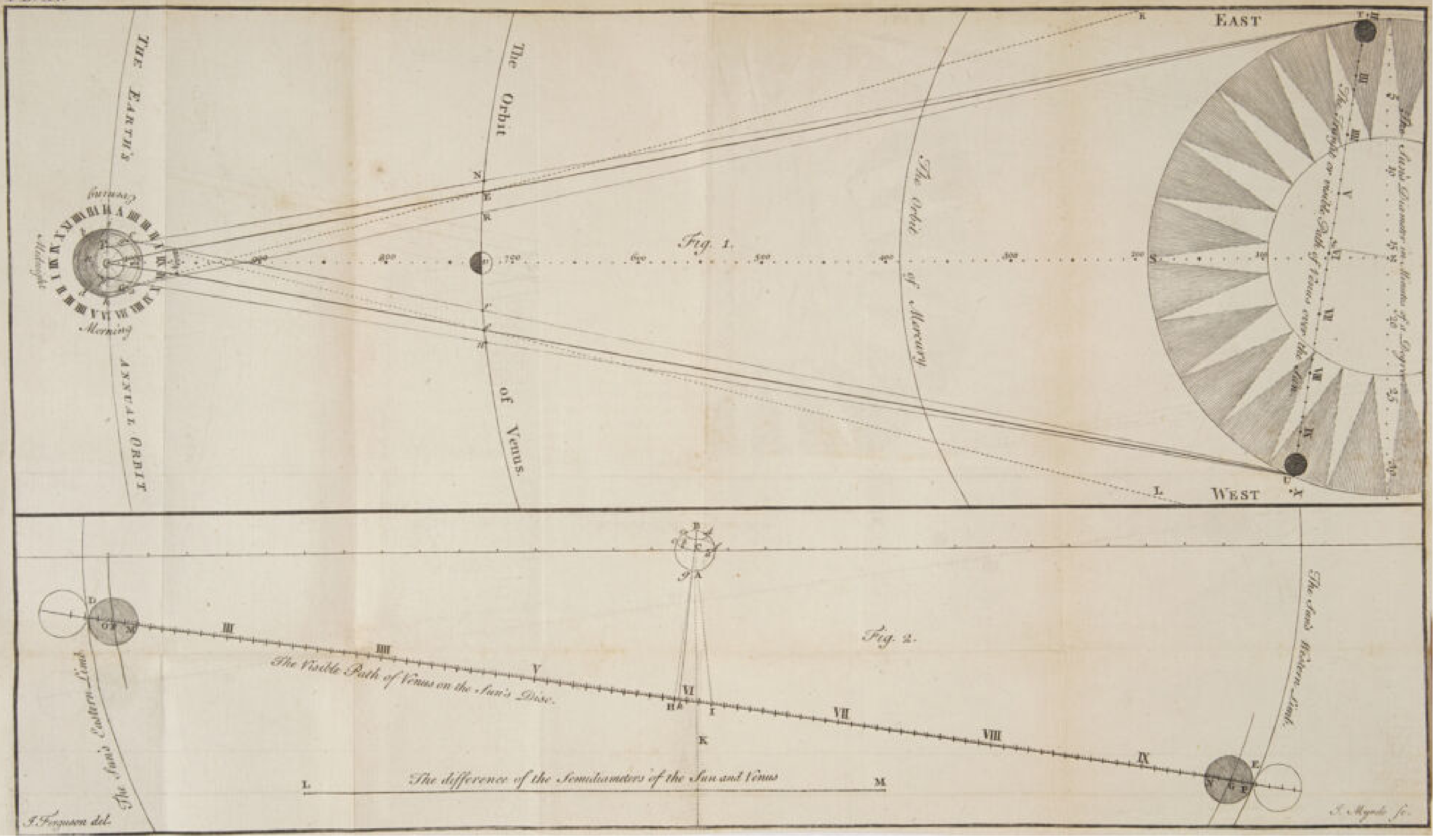
Supposing the Sun's parallax (as we have said) to be $12''\frac{1}{2}$, the parallax of Venus will be $43''$; from which subtracting the parallax of the Sun, there will remain $30''$ at least for the horizontal parallax of Venus from the Sun; and therefore the motion of Venus will be increased $45''$ at least by that parallax, whilst she passes over the Sun's disc, in those elevations of the pole which are in places near the tropic, and yet more in the neighbourhood of the equator. Now, Venus at that time will move on the Sun's disc, very nearly at the rate of four minutes of a degree in an hour; and therefore 11 minutes of time at least are to be allowed for $45''$, or three-fourths of a minute of a degree;

When the mouth of the *Ganges* is at *m* in revolving through the arc *Gmg*) the Sun is on it's meridian. Therefore, since *G* and *g* are equally distant from *m* at the beginning and ending of the transit, it is plain that the Sun will be as far east of the meridian of the *Ganges* (at *G*) when the transit begins, as it will be west of the meridian of the same place (revolved from *G* to *g*) when the transit ends.

But although the beginning of the transit, or rather the moment of Venus's total ingress upon the Sun at *T*, as seen from the Earth's center, must be when Venus is at *E* in her orbit, because she is then seen in the direction of the right line *CET*; yet, at the same instant of time, as seen from the *Ganges* at *G*, she will be short of her ingress on the Sun, being then seen eastward of him, in the right line *GEK*, which makes the angle *KET* (equal to the opposite angle *GEC*) with the right line *CET*. This angle is called the angle of Venus's parallax from the Sun, which retards the beginning of the transit as seen from the banks of the *Ganges*; so that the *Ganges* *G* must advance a little farther toward *m*, and Venus must move on in her orbit from *E* to *R*, before she can be seen from *G* (in the right line *GRT*) wholly within the Sun's disc at *T*.

When Venus comes to *e* in her orbit, she will appear at *U*, as seen from the Earth's center *C*, just beginning to leave the Sun; that is, at the beginning of her egress from his western limb: but at the same instant of time, as seen from the *Ganges*, which is then at *g*, she will be quite clear of the Sun toward the west; being then seen from *g* in the right line *geL*, which makes an angle, as *UeL* (equal to the opposite angle *Ceg*) with the right line *CeU*: and this is the angle of Venus's parallax

PL. XV.



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ting, and goes off a little after it's rising. And this will happen under the above-mentioned meridian, and where the elevation of the north pole is about 56 degrees; that is, in a part of *Hudson*'s *Bay*, near a place called *Port-Nelson*. For, in this and the adjacent places, the parallax of Venus will increase the duration of the transit by at least six minutes of time; because, whilst the Sun, from it's setting to it's rising, seems to pass under the pole, those places on the Earth's disc will be carried with a motion from east to west, contrary to the motion of the *Ganges*; that is, with a motion conspiring with the motion of Venus; and therefore, Venus will seem to move more slowly on the Sun, and to be longer in passing over his disc*.

If

* In Fig 1. of Plate XV. let *aC* be the meridian of the eastern mouth of the *Ganges*; and *bC* the meridian of *Port-Nelson* at the mouth of *York-River* in *Hudson*'s *Bay*, 56° north latitude. As the meridian of the *Ganges* revolves from *a* to *c*, the meridian of *Port-Nelson* will revolve from *b* to *d*: therefore, whilst the *Ganges* revolves from *G* to *g*, through the arc *Gmg*, *Port-Nelson* revolves the contrary way (as seen from the Sun or Venus) from *P* to *p* through the arc *Pnp*.——Now, as the motion of Venus is from *E* to *e* in her orbit, while she seems to pass over the Sun's disc in the right line *TtU*, as seen from the Earth's center *C*, it is plain, that whilst the motion of the *Ganges* is contrary to the motion of Venus in her orbit, and thereby shortens the duration of the transit at that place, the motion of *Port-Nelson* is the same way as the motion of Venus, and will therefore increase the duration of the transit: which may in some degree be illustrated by supposing, that whilst a ship is under sail, if two birds fly along the side of the ship in contrary directions to each other, the bird which flies contrary to the motion of the ship will pass by it sooner than the bird will, which flies the same way that the ship moves.

In fine, it is plain by the figure, that the duration of the transit must be longer as seen from *Port-Nelson*, than as seen from the Earth's center; and longer as seen from the Earth's center, than as seen from the mouth of the *Ganges*.——For *Port-Nelson* must be at *P*, and Venus at *N* in her orbit, when she appears wholly within the Sun at *T*: and the same place must be at *p*, and Venus at *n*, when she appears at *U*, beginning to leave the Sun.—The *Ganges* must be at *G*, and Venus at

If therefore it ſhould happen that this tranſit ſhould be properly obſerved by ſkilful perſons at both theſe places, it is clear, that the duration thereof will be 17 minutes longer, as ſeen from *Port-Nelſon*, than as ſeen from the *Eaſt-Indies*. Nor is it of much conſequence (if the *Engliſh* ſhall at that time give any attention to this affair) whether the obſervation be made at *Fort-George*, commonly called *Madras*, or at *Bencoolen* on the weſtern ſhore of the iſland of *Sumatra*, near the equator. But if the *French* ſhall be diſpoſed to take any pains herein, an obſerver may ſtation himſelf conveniently enough at *Pondicherry* on the weſt ſhore of the bay of *Bengal*, where the altitude of the pole is about 12 degrees. As to the *Dutch*, their celebrated mart at *Batavia* will afford them a place of obſervation fit enough for this purpoſe, provided they alſo have but a diſpoſition to aſſiſt in advancing, in this particular, the knowledge of the heavens.— And indeed I could wiſh that many obſervations of the ſame phenomenon might be taken by different perſons at ſeveral places, both that we might arrive at a greater degree of certainty by their agreement, and alſo leaſt any ſingle obſerver ſhould be deprived, by the intervention of clouds, of a ſight, which I know not whether any man living in this or the next age will ever ſee again; and on which depends the certain and adequate ſolution of a problem the moſt noble, and at any other time not to be attained to. I recommend it therefore, again and again, to thoſe curious Aſtronomers, who (when I am dead) will have an opportunity of obſerving theſe things, that they would remem-

at *R*, when ſhe is ſeen from *G* upon the Sun at *T*: and the ſame place muſt be at *g*, and Venus at *r*, when ſhe begins to leave the Sun at *U*, as ſeen from *g*. So that Venus muſt move from *N* to *n* in her orbit, whilſt ſhe is ſeen to paſs over the Sun from *Port-Nelſon*; from *E* to *e* in paſſing over the Sun, as ſeen from the Earth's center; and only from *R* to *r* whilſt ſhe paſſes over the Sun, as ſeen from the banks of the *Ganges*.

ber

ber this my admonition, and diligently apply themſelves with all their might to the making this obſervation; and I earneſtly wiſh them all imaginable ſucceſs; in the firſt place that they may not, by the unſeaſonable obſcurity of a cloudy ſky, be deprived of this moſt deſirable ſight; and then, that having aſcertained with more exactneſs the magnitudes of the planetary orbits, it may redound to their immortal fame and glory.

We have now ſhewn, that by this method the Sun's parallax may be inveſtigated to within it's five hundredth part, which doubtleſs will appear wonderful to ſome. But if an accurate obſervation be made in each of the places above marked out, we have already demonſtrated that the durations of this eclipſe made by Venus will differ from each other by 17 minutes of time; that is, upon a ſuppoſition that the Sun's parallax is $12''\frac{1}{2}$. But if the difference ſhall be found by obſervation to be greater or leſs, the Sun's parallax will be greater or leſs, nearly in the ſame proportion. And ſince 17 minutes of time are anſwerable to $12\frac{1}{2}$ ſeconds of ſolar parallax, for every ſecond of parallax there will ariſe a difference of more than 80 ſeconds of time; whence, if we have this difference true to two ſeconds, it will be certain what the Sun's parallax is, to within a 40th part of one ſecond; and therefore, his diſtance will be determined to within it's 500dth part at leaſt, if the parallax be not found leſs than what we have ſuppoſed: for 40 times $12\frac{1}{2}$ make 500.

And now I think I have explained this matter fully, and even more than I needed to have done, to thoſe who underſtand Aſtronomy: and I would have them take notice, that on this occaſion, I have had no regard to the latitude of Venus, both to avoid the inconvenience of a more intricate calculation, which would render the concluſion leſs evident; and alſo becauſe the motion of the nodes

of

of Venus is not yet diſcovered, nor can be determined but by ſuch conjunctions of the planet with the Sun as this is. For we conclude, that Venus will paſs 4 minutes below the Sun's center, only in conſequence of the ſuppoſition that the plane of Venus's orbit is immoveable in the ſphere of the fixed ſtars, and that it's nodes remain in the ſame places where they were found in the year 1639. But if Venus, in the year 1761, ſhould move over the Sun in a path more to the ſouth, it will be manifeſt that her nodes have moved backward among the fixed ſtars; and if more to the north, that they have moved forward; and that at the rate of $5\frac{1}{2}$ minutes of a degree in 100 Julian years, for every minute that Venus's path ſhall be more or leſs diſtant than the abovesaid 4 minutes from the Sun's center. And the difference between the durations of theſe eclipſes will be ſomewhat leſs than 17 minutes of time, on account of Venus's ſouth latitude; but greater, if by the motion of the nodes forward ſhe ſhould paſs on the north of the Sun's center.

But for the ſake of thoſe, who, though they are delighted with ſydereal obſervations, may not yet have made themſelves acquainted with the doctrine of parallaxes, I choſe to explain the thing a little more fully by a ſcheme, and alſo by a calculation ſomewhat more accurate.

Let us ſuppoſe that at *London*, in the year 1761, on the 6th of *June*, at 55 minutes after V in the morning, the Sun will be in Gemini 15° 37′, and therefore that at it's center the ecliptic is inclined toward the north, in an angle of 6° 10′: and that the viſible path of Venus on the Sun's diſc at that time declines to the ſouth, making an angle with the ecliptic of 8° 28′: then the path of Venus will alſo be inclined to the ſouth, with reſpect to the equator, interſecting the parallels of declination

nation at an angle of 2° 18′ *. Let us alſo ſuppoſe, that Venus, at the forementioned time, will be at her leaſt diſtance from the Sun's center, viz. only four minutes to the ſouth; and that every hour ſhe will deſcribe a ſpace of 4 minutes on the Sun, with a retrograde motion. The Sun's ſemidiameter will be 15′ 51″ nearly, and that of Venus 37″½. And let us ſuppoſe, for trial's ſake, that the difference of the horizontal parallaxes of Venus with the Sun (which we want) is 31″, ſuch as it comes out if the Sun's parallax be ſuppoſed 12″½. Then, on the center *C* (Plate XV. Fig. 2.) let the little circle *A B*, repreſenting the Earth's diſc, be deſcribed, and let it's ſemidiameter *C B* be 31″; and let the elliptic parallels of 22 and 56 degrees of north latitude (for the *Ganges* and *Port-Nelſon*) be drawn within it, in the manner now uſed by Aſtronomers for conſtructing ſolar eclipſes. Let *B C g* be the meridian in which the Sun is, and to this, let the right line *F H G*, repreſenting the path of Venus, be inclined at an angle of 2° 18′; and let it be diſtant from the center *C* 240 ſuch parts, whereof *C B* is 31. From *C* let fall the right line *C H*, perpendicular to *F G*; and ſuppoſe Venus to be at *H* at 55 minutes after V in the morning. Let the right line *F H G* be divided into the horary ſpaces III IV, IV V, V VI, &c. each equal to *C H*; that is, to 4 minutes of a degree. Alſo, let the right line *L M* be equal to the difference of the

* This was an overſight in the Doctor, occaſioned by his placing both the Earth's axis *B C g* (Fig. 2. of Plate XV.) and the axis of Venus's orbit *C H* on the ſame ſide of the axis of the ecliptic *C K*; the former making an angle of 6° 10′ therewith, and the latter an angle of 8° 28′; the difference of which angles is only 2° 18′. But the truth is, that the Earth's axis, and the axis of Venus's orbit, will then lie on different ſides of the axis of the ecliptic, the former making an angle of 6° therewith, and the latter an angle of 8°½. Therefore, the ſum of theſe angles, which is 14°½ (and not their difference 2° 18′) is the inclination of Venus's viſible path to the equator and parallels of declination.

apparent

apparent ſemidiameters of the Sun and Venus, which is 15′ 13″$\frac{1}{2}$; and a circle being deſcribed with the radius *L M*, on a center taken in any point within the little circle *A B* repreſenting the Earth's diſc, will meet the right line *F G* in a point denoting the time at *London* when Venus ſhall touch the Sun's limb internally as ſeen from the place of the Earth's ſurface that anſwers to the point aſſumed in the Earth's diſc. And if a circle be deſcribed on the center *C*, with the radius *L M*, it will meet the right line *F G* in the points *F* and *G*; and the ſpaces *F H* and *G H* will be each equal to 14′ 4″, which ſpace Venus will appear to paſs over in 3 hours 40 minutes of time at *London*; therefore, *F* will fall in II hours 15 minutes, and *G* in IX hours 35 minutes in the morning. Whence it is manifeſt, that if the magnitude of the Earth, on account of it's immenſe diſtance, ſhould vaniſh as it were into a point; or, if being deprived of a diurnal motion, it ſhould always have the Sun vertical to the ſame point *C*; the whole duration of this eclipſe would be 7 hours 20 minutes. But the Earth in that time being whirled through 110 degrees of longitude, with a motion contrary to the motion of Venus, and conſequently the abovementioned duration being contracted, ſuppoſe 12 minutes, it will come out 7 hours 8 minutes, or 107 degrees, nearly.

Now, Venus will be at *H*, at her leaſt diſtance from the Sun's center, when in the meridian of the eaſtern mouth of the *Ganges*, where the altitude of the pole is about 22 degrees. The Sun therefore will be equally diſtant from the meridian of that place, at the moments of the ingreſs and egreſs of the planet, viz. 53$\frac{1}{2}$ degrees; as the points *a* and *b* (repreſenting that place in the Earth's diſc *A B*) are, in the greater parallel, from the meridian *B C g*. But the diameter *e f* of that parallel will be to the diſtance *a b*, as the ſquare of the radius to the rectangle under the ſines of 53$\frac{1}{2}$ and 68 degrees; that is, as 1′ 2″ to 46″ 13‴. And by a good calculation (which, that I may not tire the reader, it is better to omit) I find, that a circle deſcribed on *a* as a center, with the radius *L M*, will meet the right line *F H* in the point *M*, at II hours 20 minutes 40 ſeconds; but that being deſcribed round *b* as a center, it will meet *H G* in the point *N* at IX hours 29 minutes 22 ſeconds, according to the time reckoned at *London:* and therefore, Venus will be ſeen entirely within the Sun at the banks of the *Ganges* for 7 hours 8 minutes 42 ſeconds: we have then rightly ſuppoſed, that the duration will be 7 hours 8 minutes, ſince the part of a minute is here of no conſequence.

But adapting the calculation to *Port-Nelſon*, I find, that the Sun being about to ſet, Venus will enter his diſc; and immediately after his riſing ſhe will leave the ſame. That place is carried in the intermediate time through the hemiſphere oppoſite to the Sun, from *c* to *d*, with a motion conſpiring with the motion of Venus; and therefore, the ſtay of Venus on the Sun will be about 4 minutes longer, on account of the parallax; ſo that it will be at leaſt 7 hours 24 minutes, or 111 degrees of the equator. And ſince the latitude of the place is 56 degrees, as the ſquare of the radius is to the rectangle contained under the ſines $55\frac{1}{2}$ and 34 degrees, ſo is *A B*, which is 1′ 2″, to *c d*, which is 28″ 33‴. And if the calculation be juſtly made, it will appear, that a circle deſcribed on *c* as a center, with the radius *L M*, will meet the right line *F H* in *O*, at II hours 12 minutes 45 ſeconds; and that ſuch a circle, deſcribed on *d* as a center, will meet *H G* in *P*, at IX hours 36 minutes 37 ſeconds; and therefore the duration at *Port-Nelſon* will be 7 hours 23 minutes 52 ſeconds, which is greater than at the mouth of the *Ganges*, by 15 minutes 10 ſeconds of time. But if Venus ſhould paſs over the Sun without having any latitude, the difference would be 18 minutes 40 ſeconds; and if ſhe ſhould paſs 4′ north of the Sun's center, the difference would amount to 21 minutes 40 ſeconds, and will be ſtill greater, if the planet's north latitude be more increaſed.

From the foregoing hypotheſis it follows, that at *London*, when the Sun riſes, Venus will have entered his diſc; and that, at IX hours 37 minutes in the morning, ſhe will touch the limb of the Sun internally in going off; and laſtly, that ſhe will not entirely leave the Sun till IX hours 56 minutes.

It likewiſe follows from the ſame hypotheſis, that the center of Venus ſhould juſt touch the Sun's northern limb in the year 1769, on the third of *June*, at XI o'clock at night. So that, on account of the parallax, it will appear in the northern parts of *Norway* entirely within the Sun, which then does not ſet to thoſe parts; whilſt, on the coaſts of *Peru* and *Chili*, it will ſeem to travel over a ſmall portion of the diſc of the ſetting Sun; and over that of the riſing Sun at the *Molucca Iſlands*, and in their neighbourhood.—But if the nodes of Venus be found to have a retrograde motion (as there is ſome reaſon to believe from ſome later obſervations they have) then Venus will be ſeen every where within the Sun's diſc; and will afford a much better method for finding the Sun's parallax, by almoſt the greateſt difference in the duration of theſe eclipſes that can poſſibly happen.

But how this parallax may be deduced from obſervations made ſomewhere in the *Eaſt-Indies*, in the year 1761, both of the ingreſs and egreſs of Venus, and compared with thoſe made in it's going off with us; namely, by applying the angles of a triangle given in ſpecie to the circumference of three equal circles; ſhall be explained on ſome other occaſion.

ARTICLE IV.

Shewing that the whole method propoſed by the Doctor cannot be put in practice, and why.

27. In the above Diſſertation, the Doctor has explained his method with great modeſty, and even with ſome doubtfulneſs with regard to it's full ſucceſs. For he tells us, that the Sun's parallax may only be determined within it's five hundredth part thereby, provided it be not leſs than $12''\frac{1}{2}$; that there may be a good obſervation made at *Port-Nelſon*, as well as about the banks of the *Ganges*; and that Venus does not paſs more than 4 minutes of a degree below the center of the Sun's diſc.—He has taken all proper pains not to raiſe our expectations too high, and yet, from his well-known abilities, and character as a great Aſtronomer, it ſeems mankind in general have laid greater ſtreſs upon his method, than he ever deſired them to do. Only, as he was convinced it was the beſt method by which this important problem can ever be ſolved, he recommended it warmly for that reaſon. He had not then made a ſufficient number of obſervations, whereby to determine, with certainty, whether the nodes of Venus's orbit have any motion at all; or, if they have, whether it be backward or forward with reſpect to the ſtars. And conſequently, having not then made his own tables, he was obliged to calculate from the beſt that he could find. But thoſe tables allow of no motion to Venus's nodes, and alſo reckon her conjunction with the Sun to be about half an hour too late.

28. But more modern obſervations prove, that the nodes of Venus's orbit have a motion, backward, or contrary to the order of the ſigns, with reſpect to the fixed ſtars. And this motion is allowed for, in the Doctor's tables, a great part whereof were made from his own obſervations.

And

And it appears by theſe tables, that Venus will be ſo much farther paſt her deſcending node at the time of this tranſit, than ſhe was paſt her aſcending node at her tranſit in *November* 1639, that inſtead of paſſing only 4 minutes of a degree below the Sun's center in this, ſhe will paſs almoſt 10 minutes of a degree below it: on which account, the line of her tranſit will be ſo much ſhortened, as will make her paſſage over the Sun's diſc about an hour and 20 minutes leſs than if ſhe paſſed only 4 minutes below the Sun's center, at the middle of her tranſit. And therefore, her parallax from the the Sun will be ſo much diminiſhed, both at the beginning and end of her tranſit, and at all places from which the whole of it will be ſeen, that the difference of it's durations, as ſeen from them, and as ſuppoſed to be ſeen from the Earth's center, will not amount to 11 minutes of time.

29. But this is not all: for although the tranſit will begin before the Sun ſets to *Port-Nelſon*, it will be quite over before he riſes to that place next morning, on account of it's ending ſo much ſooner than as given by the tables to which the Doctor was obliged to truſt. So that we are quite deprived of the advantage that otherwiſe would have ariſen from obſervations made at *Port-Nelſon*.

30. In order to trace this affair through all it's intricacies, and to render it as intelligible to the reader as I can, there will be an unavoidable neceſſity of dwelling much longer upon it than I could otherwiſe wiſh. And as it is impoſſible to lay down truly the parallels of latitude, and the ſituations of places at particular times, in ſuch a ſmall diſc of the Earth as muſt be projected in ſuch a ſort of diagram as the Doctor has given, ſo as to meaſure thereby the exact times of the beginning and ending of the tranſit at any given place, unleſs the Sun's diſc be made at leaſt 30 inches diameter in the projection; and to which the Doctor did not quite truſt without making ſome calculations; I

 ſhall

ſhall take a different method, in which the Earth's diſc may be made as large as the operator pleaſes: but if he makes it only 6 inches in diameter, he may meaſure the quantity of Venus's parallax from the Sun upon it, both in longitude and latitude, to the fourth part of a ſecond, for any given time and place; and then, by an eaſy calculation in the common rule of three, he may find the effect of the parallaxes on the duration of the tranſit. In this, I ſhall firſt ſuppoſe with the Doctor, that the Sun's horizontal parallax is $12''\frac{1}{2}$; and conſequently, that Venus's horizontal parallax from the Sun is $31''$. And after projecting the tranſit, ſo as to find the total effect of the parallax upon it's duration, I ſhall next ſhew how nearly the Sun's real parallax may be found from the obſerved intervals between the times of Venus's egreſs from the Sun, at particular places of the Earth; which is the method now taken both by the *Engliſh* and *French* Aſtronomers, and is a ſurer way whereby to come at the real quantity of the Sun's parallax, than by obſerving how much the whole contraction of duration of the tranſit is, either at *Bencoolen*, *Batavia*, or *Pondicherry*.

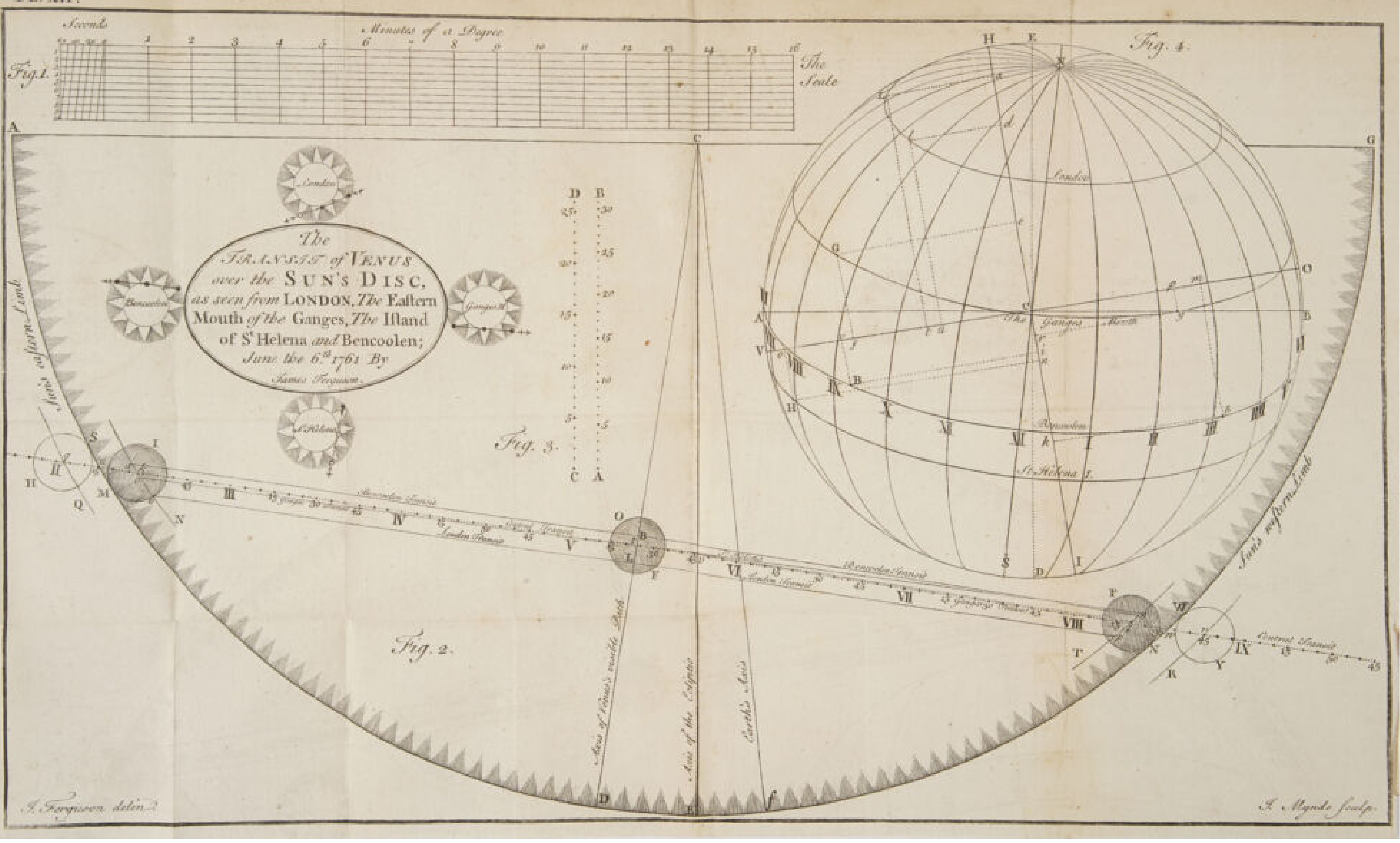
ARTICLE V.

Shewing how to project the tranſit of Venus on the Sun's diſc, as ſeen from different places of the Earth; ſo as to find what it's viſible duration muſt be at any given place, according to any aſſumed parallax of the Sun; and from the obſerved intervals between the times of Venus's egreſs from the Sun at particular places, to find the Sun's true horizontal parallax.

31. The elements for this projection are as follows:

I. The true time of conjunction of the Sun and Venus; which, as ſeen from the Earth's center, and reckoned according to the equal time at *London*,

PL. XVI.



The TRANSIT of VENUS over the SUN's DISC, as seen from LONDON, The Eastern Mouth of the Ganges, The Island of St Helena and Bencoolen; June the 6th 1761 By James Ferguson.
Seconds
Minutes of a Degree
Fig. 1.
The Scale
Fig. 2.
Fig. 3.
Fig. 4.
London
Bencoolen
St Helena
Sun's eastern Limb
Sun's western Limb
Axis of Venus's visible Path
Axis of the Ecliptic
Earth's Axis
London Transit
Bencoolen Transit
Central Transit
The Ganges Mouth
J. Ferguson delin.
J. Mynde sculp.

London, is on the 6th of *June* 1761, at 46 minutes 17 seconds after V in the morning, according to Dr. HALLEY's tables.

II. The geocentric latitude of Venus at that time, 9′ 43″ south.

III. The Sun's semidiameter, 15′ 50″.

IV. The semidiameter of Venus (from the Doctor's Dissertation) 37″ $\frac{1}{2}$.

V. The difference of the semidiameters of the Sun and Venus, 15′ 12″ $\frac{1}{2}$.

VI. Their sum, 16′ 27″ $\frac{1}{2}$.

VII. The visible angle which the transit-line makes with the ecliptic, 8° 31′; the angular point (or descending node) being 1° 6′ 18″ eastward from the Sun, as seen from the Earth; the descending node being in ♐ 14° 29′ 37″, as seen from the Sun; and the Sun in ♊ 15° 35′ 55″, as seen from the Earth.

VIII. The angle which the axis of Venus's visible path makes with the axis of the ecliptic, 8° 31′; the southern half of that axis being on the left hand (or eastward) of the axis of the ecliptic, as seen from the northern hemisphere of the Earth, which would be to the right hand, as seen from the Sun.

IX. The angle which the Earth's axis makes with the axis of the ecliptic, as seen from the Sun, 6°; the southern half of the Earth's axis lying to the right hand of the axis of the ecliptic, in the projection; which would be to the left hand as seen from the Sun.

X. The angle which the Earth's axis makes with the axis of Venus's visible path, 14° 31′; viz. the sum of N° VIII and IX.

XI. The true motion of Venus on the Sun, given by the tables as if it were seen from the Earth's center, 4 minutes of a degree in 60 minutes of time.

32. These elements being collected, make a scale of any convenient length, as that of Fig. 1. in Plate XVI. and divide it into 17 equal parts, each whereof shall be taken for a minute of a degree; then, divide the minute next to the left hand into 60 equal parts for seconds, by diagonal lines, as in the figure. The reason for dividing the scale into 17 parts or minutes is, because the sum of the semidiameters of the Sun and Venus exceeds 16 minutes of a degree. See N° VI.

33. Draw the right line *ACG* (Fig. 2.) for a small part of the ecliptic, and perpendicular thereto draw the right line *CvE* for the axis of the ecliptic on the southern half of the Sun's disc.

34. Take the Sun's semidiameter, 15′ 50″, from the scale with your compasses; and with that extent, as a radius, set one foot in *C* as a center, and describe the semicircle *AEG* for the southern half of the Sun's disc; because the transit is on that half of the Sun.

35. Take the geocentric latitude of Venus, 9′ 43″, from the scale with your compasses; and set that extent from *C* to *v*, on the axis of the ecliptic: and the point *v* shall be the place of Venus's center on the Sun, at the tabular moment of her conjunction with the Sun.

36. Draw the right line *CBD*, making an angle of 8° 31′ with the axis of the ecliptic, toward the left hand; and this line shall represent the axis of Venus's geocentric visible path on the Sun.

37. Through the point of the conjunction *v*, in the axis of the ecliptic, draw the right line *qtr* for the geocentric visible path of Venus over the Sun's disc, at right angles to *CBD*, the axis of her orbit, which axis will divide the line of her path into two equal parts *qt* and *tr*.

38. Take Venus's horary motion on the Sun, 4′, from the scale with your compasses; and with that extent make marks along the transit-line *qtr*. The equal spaces, from mark to mark, shew how much

much of that line Venus moves through in each hour, as ſeen from the Earth's center, during her continuance on the Sun's diſc.

39. Divide each of theſe horary ſpaces, from mark to mark, into 60 equal parts for minutes of time; and ſet the hours to the proper marks in ſuch a manner, that the true time of conjunction of the Sun and Venus, $46\frac{1}{4}$ minutes after V in the morning, may fall into the point *v*, where the tranſit-line cuts the axis of the ecliptic. So the point *v* ſhall denote the place of Venus's center on the Sun, at the inſtant of her ecliptical conjunction with the Sun, and *t* (in the axis *C t D* of her orbit) will be the middle of her tranſit; which is at 24 minutes after V in the morning, as ſeen from the Earth's center, and reckoned by the equal time at *London*.

40. Take the difference of the ſemidiameters of the Sun and Venus, $15' \; 12''\frac{1}{2}$, in your compaſſes from the ſcale; and with that extent, ſetting one foot in the Sun's center *C*, deſcribe the arcs *N* and *T* with the other, croſſing the tranſit-line in the points *k* and *l*; which are the points on the Sun's diſc that are hid by the center of Venus at the moments of her two internal contacts with the Sun's limb or edge, at *M* and *N:* the former of theſe is the moment of Venus's total ingreſs on the Sun, as ſeen from the Earth's center, which is at 28 minutes after II in the morning, as reckoned at *London*; and the latter is the moment when her egreſs from the Sun begins, as ſeen from the Earth's center, which is 20 minutes after VIII in the morning at *London*. The interval between theſe two contacts is 5 hours 52 minutes.

41. The central ingreſs of Venus on the Sun is the moment when her center is on the Sun's eaſtern limb at *u*, which is at 15 minutes after II in the morning; and her central egreſs from the Sun is the moment when her center is on the Sun's weſtern limb at *w*; which is at 33 minutes after VIII in the

of Venus's parallax either from or upon the Sun (her horizontal parallax from the Sun being ſuppoſed to be 31′;) and taking the whole length *AB* in your compaſſes, ſet one foot in *C* (Fig. 4.) as a center, and deſcribe the circle *AEBD* for the Earth's enlightened diſc, whoſe diameter is 62″, or double the horizontal parallax of Venus from the Sun. In this diſc, draw *ACB* for a ſmall part of the ecliptic, and at right angles thereto draw *ECD* for the axis of the ecliptic. Draw alſo *NCS* both for the Earth's axis and univerſal ſolar meridian, making an angle of 6° with the axis of the ecliptic, as ſeen from the Sun; *HCI* for the axis of Venus's orbit, making an angle of 8° 31′ with *ECD*, the axis of the ecliptic; and laſtly, *VCO* for a ſmall part of Venus's orbit, at right angles to it's axis.

46. This figure repreſents the Earth's enlightened diſc, as ſeen from the Sun at the time of the tranſit. The parallels of latitude of *London*, the eaſtern mouth of the *Ganges*, *Bencoolen*, and the iſland of *St. Helena*, are laid down in it, in the ſame manner as they would appear to an obſerver on the Sun, if they were really drawn in circles on the Earth's ſurface (like thoſe on a common terreſtrial globe) and could be viſible at ſuch a diſtance.—The method of delineating theſe parallels is the ſame as already deſcribed in the XIXth Chapter, for the conſtruction of ſolar eclipſes.

47. The points where the curve-lines (called hour-circles) XI *N*, X *N*, &c. cut the parallels of latitude, or paths of the four places above-mentioned, are the points at which the places themſelves would appear in the diſc, as ſeen from the Sun, at theſe hours reſpectively. When either place comes to the ſolar meridian *NCS* by the Earth's rotation on it's axis, it is noon at that place; and the difference, in abſolute time, between the noon at that place and the noon at any other place, is in proportion to the difference of longitude of of theſe two places, reckoning one hour for every

15 de-

15 degrees of longitude, and 4 minutes for each degree: adding the time if the longitude be eaſt, but ſubtracting it if the longitude be weſt.

48. The diſtance of either of theſe places from *HCI* (the axis of Venus's* orbit) at any hour or part of an hour, being meaſured upon the ſcale *AB* in Fig. 3. will be equal to Venus's parallax in longitude, either on or from the Sun; and this parallax, being always contrary to the poſition of the place, is eaſtward as long as the place keeps on the left hand of the axis of the ecliptic, as ſeen from the Sun; and weſtward when the place gets to the right hand of the axis of the ecliptic. So that, to all the places which are poſited in the hemiſphere *HVI* of the diſc, at any given time, Venus has an eaſtern parallax of longitude; but when the Earth's diurnal motion carries the ſame places into the hemiſphere *HOI*, the parallax of Venus is weſtward.

49. When Venus has a parallax toward the eaſt, as ſeen from any given place on the Earth's ſurface, either at the time of her total ingreſs or beginning of egreſs, as ſeen from the Earth's center; add the time anſwering to this parallax to the time of ingreſs or egreſs at the Earth's center, and the ſum will be the time thereof, as ſeen from the given place on the Earth's ſurface: but when the parallax is weſtward, ſubtract the time anſwering thereto from the time of total ingreſs or beginning of egreſs as ſeen from the Earth's center, and the remainder will be the time as ſeen from the given place on the ſurface, ſo far as it is affected by this

* In the former Edition of this, I made a miſtake in taking the parallax in longitude in a line from the given place to the axis of the ecliptic, and perpendicular thereto; and the parallax in latitude from the given place to the plane of the ecliptic, and perpendicular thereto.—But in this edition, theſe errors are corrected; which make ſome ſmall differences in the quantities of the parallaxes, and in the times depending thereon; as will appear by comparing them in this with thoſe in the former edition.

paral-

parallax.—The reaſon of this is plain to every one who conſiders, that an eaſtern parallax keeps the planet back, and a weſtern parallax carries it forward, with reſpect to its true place or poſition, at any inſtant of time, as ſeen from the Earth's center.

50. The neareſt diſtance of any given place from *VCO*, the plane of Venus's orbit at any hour or part of an hour, being meaſured on the ſcale *AB* in Fig. 3, will be equal to Venus's parallax in latitude, which is northward from the true line of her path on the Sun as ſeen from the Earth's center, if the given place be on the ſouth ſide of the plane of her orbit *VCO* on the Earth's diſc; and the contrary, if the given place be on the north ſide of that plane; that is, the parallax is always contrary to the ſituation of the place on the Earth's diſc, with reſpect to the plane of Venus's orbit thereon.

51. As the line of Venus's tranſit is on the ſouthern hemiſphere of the Sun's diſc, it is plain that a northern parallax in her latitude will cauſe her to deſcribe a longer line on the Sun, than if ſhe had no ſuch parallax; and a ſouthern parallax in latitude will cauſe her to deſcribe a ſhorter line on the Sun, than if ſhe had no ſuch parallax.—And the longer this line is, the ſooner will her total ingreſs be, and the later will be her beginning of egreſs; and juſt the contrary, if the line be ſhorter.—But, to all places ſituated on the north ſide of the plane of her orbit, in the hemiſphere *VHO*, the parallax of latitude is ſouth; and to all places ſituated on the ſouth ſide of the plane of her orbit, in the hemiſphere *VIO*, the parallax of latitude is north. Therefore, the line of the tranſit will be ſhorter to all places in the hemiſphere *VHO*, than it will be as ſeen from the Earth's center, where there is no parallax at all; and longer to all places in the hemiſphere *VIO*. So that the time anſwering to this parallax muſt be added to the time of total ingreſs as ſeen from the Earth's center, and ſubtracted from

the

the beginning of egrefs as feen from the Earth's center, in order to have the true time of total ingrefs and beginning of egrefs as feen from places in the hemifphere *VHO*: and juft the reverfe for places in the hemifphere *VIO*.—It was proper to mention thefe circumftances, for the reader's more eafily conceiving the reafon of applying the times anfwering to the parallaxes of longitude and latitude in the fubfequent part of this article: for it is their fum in fome cafes, and their difference in others, which being applied to the times of total ingrefs and beginning of egrefs as feen from the Earth's center, that will give the times thereof as feen from the given places on the Earth's furface.

52. The angle which the Sun's femidiameter fubtends, as feen from the Earth, at all times of the year, has been fo well afcertained by late obfervations, that we can make no doubt of it's being 15′ 50″ on the day of the tranfit; and Venus's latitude has alfo been fo well afcertained at many different times of late, that we have very good reafon to believe it will be 9′ 43″ fouth of the Sun's center, at the time of her conjunction with the Sun.—If then, her femidiameter at that time be 37″ ½ (as mentioned by Dr. HALLEY) it appears by the projection (Fig. 2.) that her total ingrefs on the Sun as feen from the Earth's center, will be at 28 minutes after II in the morning (§ 40.) and her beginning of egrefs from the Sun will be 20 minutes after VIII, according to the time reckoned at *London*.

53. As the total ingrefs will not be vifible at *London*, we fhall not here trouble the reader about Venus's parallax at that time.—But by projecting the fituation of *London* on the Earth's difc (Fig. 4.) for the time when the egrefs begins, we find it will then be at *l*, as feen from the Sun.

Draw *ld* parallel to Venus's orbit *VCO*, and *lu* perpendicular to it: the former is Venus's eaftern parallax in longitude at her beginning of egrefs, and

56. At V hours 24 minutes (which is the middle of the transit as seen from the Earth's center) *London* will be at *L* on the Earth's disc (Fig. 4.) as seen from the Sun. The parallax of longitude *La* is then 12″$\frac{1}{2}$; by which, working as above directed, we find the middle of the transit, as seen from *London*, to be at V hours 20 minutes 53 seconds.—This is not affected by the parallax of latitude *Lt*.—But *Lt* measures 27″ on the scale *AB* (Fig. 3.) therefore take 27″ from the scale in Fig. 1. and set it from *t* to *L*, on the axis of Venus's path in Fig. 2. and laying a ruler to the point *L*, and the above-found point of egress *p*, draw *o L p* for the line of the transit as seen from *London*.

57. The eastern mouth of the river *Ganges* is 89 degrees east from the meridian of *London*; and therefore, when the time at *London* is 28 minutes after II in the morning (§ 40.) it is 24 minutes past VIII in the morning (by § 47.) at the mouth of the *Ganges*; and when it is 20 minutes past VIII in the morning at *London* (§ 40.) it is 16 minutes past II in the afternoon at the *Ganges*. Therefore, by projecting that place upon the Earth's disc, as seen from the Sun, it will be at *G* (in Fig. 4.) at the time of Venus's total ingress, as seen from the Earth's center, and at *g* when her egress begins.

Draw *Ge* and *gr* parallel to the orbit of Venus *VCO*, and measure them on the scale *AB* in Fig. 3. the former will be 21″ for Venus's eastern parallax in longitude, at the above-mentioned time of her total ingress, and the latter will be 16″$\frac{1}{4}$ for her western parallax in longitude at the time when her egress begins.—The former parallax gives 5 minutes 15 seconds of time (by the analogy in § 54.) to be added to VIII hours 24 minutes, and the latter parallax gives 4 minutes 11 seconds to be subtracted from II hours 16 minutes; by which we have VIII hours 29 minutes 15 seconds, for the time of total ingress as seen from the banks of the *Ganges*, and II hours

hours 11 minutes 49 ſeconds for the beginning of egreſs, as affected by theſe parallaxes.

Draw *G f* perpendicular to Venus's orbit *V O C*, and by meaſurement on the ſcale *A B* (Fig. 3.) it will be found to contain 10″; which being taken from the ſcale in Fig. 1. and ſet off ſouthward from the point of total ingreſs *k* (Fig. 2. as ſeen from the Earth's center) parallel to the axis of Venus's path, it will fall into the point *c* on the arc *N*.—Draw *C t*, and taking the extent *t c* in your compaſſes, and applying it from *t* towards *k*, you will find it to fall a minute ſhort of *k*; which ſhews, that Venus's parallax in latitude ſhortens the beginning of the line of her viſible tranſit at the *Ganges* by one minute of time. Therefore, as this makes the viſible ingreſs a minute later, add one minute to the above VIII hours 29 minutes 15 ſeconds, and it will give VIII hours 30 minutes 15 ſeconds for the time of total ingreſs, in the morning, as ſeen from the eaſtern mouth of the *Ganges*. At the beginning of egreſs, the parallax of latitude *g p* is $2''\frac{1}{2}$ (by meaſurement of the ſcale *AB*) which will protract the beginning of egreſs by about 30 ſeconds of time, and muſt therefore be added to the above II hours 11 minutes 49 ſeconds, which will make the viſible beginning of egreſs to be at II hours 12 minutes 19 ſeconds in the afternoon.

58. *Bencoolen* is 102 degrees eaſt from the meridian of *London*; and therefore, when the time is 28 minutes paſt II in the morning at *London*, it is 16 minutes paſt IX in the morning at *Bencoolen*; and when it is 20 minutes paſt VIII in the morning at *London*, it is 8 minutes paſt III in the afternoon at *Bencoolen*. Therefore, in Fig. 4. *Bencoolen* will be at *B* at the time of Venus's total ingreſs as ſeen the Earth's center; and at *b* when her egreſs begins.

Draw *B i* and *b k* parallel to Venus's orbit *V C O*, and meaſure them on the ſcale: the former will be found to be 22″ for Venus's eaſtern parallax in longitude at the time of her total ingress; and the latter to be 19″½ for her western parallax in longitude when her egress begins, as seen from the Earth's center. The first of these parallaxes gives 5 minutes 30 seconds (by the analogy in § 54.) to be added to IX hours 16 minutes, and the latter parallax gives 4 minutes 52 seconds to be subtracted from III hours 8 minutes; whence we have IX hours 21 minutes 30 seconds for the time of total ingress at *Bencoolen*; and III hours and 3 minutes 8 seconds for the time when the egress begins there, as affected by these two parallaxes.

59. Draw *B v* and *b m* perpendicular to Venus's orbit *V C O*, and measure them on the scale *A B*: the former will be 5″ for Venus's northern parallax in latitude as seen from *Bencoolen* at the time of her total ingress; and the latter will be 15″½ for her northern parallax in latitude when her egress begins. Take these parallaxes from the scale in Fig. 1. in your compasses, and set them off above the central transit-line, perpendicular to the axis of Venus's path; the former from the left hand of *k* (Fig. 2.) to *a* in the arc *N*, and the latter from the right hand of *l* to *b* in the arc *T*; and draw *a B b* for the line of Venus's transit as seen from *Bencoolen*: the center of Venus being at *a*, as seen from *Bencoolen*, at the moment of her total ingress; and at *b* at the moment when her egress begins.

But as seen from the Earth's center, the center of Venus is at *k* in the former case, and at *l* in the latter: so that we find the line of the transit is longer as seen from *Bencoolen* than as seen from the Earth's center, which is the effect of Venus's northern parallax in latitude.—Take *B a* in your compasses, and setting that extent backward from *t* toward *g*, on the central transit-line, you will find it will reach two minutes beyond *k* thereon: and taking the extent *B b* in your compasses, and setting it forward from *t* towards *w*, on the central transit-line, it will be found to reach 3 minutes beyond

beyond l thereon. Consequently, if we subtract 2 minutes from IX hours 21 minutes 30 seconds (above found) we have IX hours 19 minutes 30 seconds, in the morning, for the time of total ingress as seen from *Bencoolen:* and if we add 3 minutes to the above found III hours 3 minutes 8 seconds, we shall have III hours 6 minutes 8 seconds after noon, for the time when the egress begins as seen from *Bencoolen.*

60. The whole duration of the transit, from total ingress to beginning of egress, as seen from the Earth's center, is 5 hours 52 minutes (by § 40.) but the whole duration from total ingress to beginning of egress, as seen from *Bencoolen*, is only 5 hours 46 minutes 38 seconds; which is 5 minutes 22 seconds less than as seen from the Earth's center: and this 5 minutes 22 seconds is the whole effect of the parallaxes (both in longitude and latitude) on the duration of the transit at *Bencoolen.*

But the duration as seen at the mouth of the *Ganges*, from ingress to egress, is still less; for it is only 5 hours 42 minutes 4 seconds: which is 9 minutes 56 seconds less than as seen from the Earth's center, and 4 minutes 34 seconds less than as seen at *Bencoolen.*

61. The island of *St. Helena* (to which only a small part of the transit is visible at the end) will be at H (as in Fig. 4.) when the egress begins as seen from the Earth's center. And since the middle of that island is 6° west from the meridian of *London*, and the said egress begins when the time at *London* is 20 minutes past VIII in the morning, it will then be only 56 minutes past VII in the morning at *St. Helena.*

Draw Hn parallel to Venus's orbit VCO, and Ho perpendicular to it; and by measuring them on the scale AB (Fig. 3.) the former will be found to amount to 29″ for Venus's eastern parallax in longitude, as seen from *St. Helena*, when her egress begins as feen from the Earth's center; and the latter to be 6″ for her northern parallax in latitude at that time.

By the analogy in § 54, this parallax of longitude gives 10 minutes 2 feconds of time; which being added (on account of it's being eaftward) to VII hours 56 minutes, gives VIII hours 6 minutes 2 feconds for the beginning of egrefs at *St. Helena*, as affected by this parallax.—But 6″ of parallax in latitude (applied as in the cafe of *Bencoolen*) lengthens out the end of the tranfit-line by 1 minute; which being added to VIII hours 6 minutes 2 feconds, gives VIII hours 7 minutes 2 feconds for the beginning of egrefs, as feen from *St. Helena*.

62. We fhall now collect the above-mentioned times into a fmall table, that they may be feen at once, as follows. *M* fignifies morning, *A* afternoon.

	Total ingrefs. H. M. S.	Beg. of egrefs. H. M. S.	Duration. H. M. S.
At The Earth's center	II 28 0 *M.*	VIII 20 0 *M.*	5 52 0*
At *London* - - -	Invifible. *M.*	VIII 17 41 *M.*	— — —
At The *Ganges* mouth	VIII 30 15 *M.*	II 12 19 *A.*	5 42 4
At *Bencoolen* - - -	IX 19 30 *M.*	III 6 8 *A.*	5 46 38
At *St. Helena* - - -	Invifible *M.*	VIII 7 2 *M.*	— — —

63. The times at the three laft-mentioned places are reduced to the meridian of *London*, by fubtracting 5 hours 56 minutes from the times of ingrefs and egrefs at the *Ganges*; 6 hours 48 minutes from the times thereof at *Bencoolen*; and adding 24 minutes to the time of beginning of egrefs at

* This duration, as feen from the Earth's center, is on fuppofition that the femidiameter of Venus will be found equal to 37″ ½, on the Sun's difc, as ftated by Dr. *Halley* (fee Art. V. § 31.) to which all the other durations are accommodated — But, from later obfervations, it his highly probable, that the femidiameter of Venus will be found not to exceed 30″ on the Sun; and if fo, the duration between the two internal contacts, as feen from the Earth's center, will be 5 hours 58 minutes; and the durations, as feen from the above-mentioned places, will be lengthened very nearly in the fame proportion.

St.

St. Helena: and being thus reduced, they are as follows.

		Total ingreſs. H. M. S.	Beg. of egreſs. H. M. S.	
Times at London for	*Ganges* mouth	II 34 15 *M.*	VIII 16 19 *M.*	Durations as above.
	Bencoolen	II 31 30 *M.*	VIII 18 8 *M.*	
	St. Helena	Inviſible. *M.*	VIII 31 2 *M.*	

64. All this is on ſuppoſition, that we have the true longitudes of the three laſt-mentioned places, that the Sun's horizontal parallax is $12''\frac{1}{2}$, that the true latitude of Venus is given, and that her ſemi-diameter will ſubtend an angle of $37''\frac{1}{2}$ on the Sun's diſc.

As for the longitudes, we muſt ſuppoſe them true, until the obſervers aſcertain them, which is a very important part of their buſineſs; and without which they can by no means find the interval of abſolute time that elapſeth between either the ingreſs or egreſs, as ſeen from any two given places: and there is much greater dependance to be had on this elapſe, than upon the whole contraction of duration at any given place, as it will undoubtedly afford a ſurer baſis for determining the Sun's parallax.

65. I have good reaſon to believe, that the latitude of Venus, as given in § 31, will be found by obſervation to be very near the truth; but that the time of conjunction there mentioned will be found to anticipate the true time by almoſt 5 minutes; that Venus's ſemidiameter will ſubtend an angle of no more than $30''$ on the Sun's diſc; and that the middle of her tranſit, as ſeen from the Earth's center, will be at 29 minutes after V in the morning, as reckoned by the equal time at *London.*

66. Subtract VIII hours 17 minutes 41 ſeconds, the time when the egreſs begins at *London*, from VIII hours 31 minutes 2 ſeconds, the time reckoned at *London* when the egreſs begins at *St. Helena*, and there will remain 13 minutes 21 ſeconds (or 801

 ſeconds)

seconds) for their difference, or elapse, in absolute time, between the beginning of egress as seen from these two places.

Divide this elapse of 801 seconds by the Sun's parallax $12''\frac{1}{2}$, and the quotient will be 64 seconds and a small fraction. So that for each second of a degree in the Sun's horizontal parallax (supposing it to be $12\frac{1}{2}$) there will be a difference or elapse of 64 seconds of absolute time between the beginning of egress as seen from *London*, and as seen from *St. Helena*: and consequently 32 seconds of time for every half second of the Sun's parallax; 16 seconds of time for every fourth part of a second of the Sun's parallax; 8 seconds of time for the eighth part of a second of the Sun's parallax; and full 4 seconds for a sixteenth part of the Sun's parallax.

For, in such a small angle as that of the Sun's parallax, the arc is equal both to it's sine and to it's tangent: and therefore, the quantity of this parallax is in direct proportion to the absolute difference in the time of egress arising from it, at different parts of the Earth.

67. Therefore, when this difference is ascertained by good observations, made at different places, and compared together, the true quantity of the Sun's parallax will be very nearly determined. For, since it may be presumed that the beginning of egress can be observed within 2 seconds of it's real time, the Sun's parallax may be then found within the 32d part of a second of it's true quantity; and consequently, his distance may be found within a 400th part of the whole, provided his parallax be not less that $12''\frac{1}{2}$; for 32 times $12\frac{1}{2}$ is 400.

68. But since Dr. HALLEY has assured us, that he had observed the two internal contacts of the planet Mercury with the Sun's edge so exactly, as not to err one second in the time thereof, we may well imagine that the internal contacts of Venus with the Sun may be observed with as great

great accuracy. So that we may hope to have the absolute interval between the moments of her beginning of egress, as seen from *London* and from *St. Helena*, true to a second of time; and if so, the Sun's parallax may be determined to the 64th part of a second, provided it be not less than $12''\frac{1}{2}$; and consequently his distance may be found, within it's 800th part, for 64 times $12\frac{1}{2}$ is 800: which is still nearer the truth than Dr. HALLEY expected it might be found, by observing the whole duration of the transit in the *East-Indies* and at *Port-Nelson*. So that our present Astronomers have judiciously resolved to improve the Doctor's method, by taking only the interval between the absolute times of it's ending at different places. If the Sun's parallax be greater or less than $12''\frac{1}{2}$, the elapse or difference of absolute time between the beginning of egress at *London* and *St. Helena* will be found by observation to be greater or less than 801 seconds accordingly.

69. There will also be a great difference between the absolute times of egress at *St. Helena* and the northern parts of *Russia*, which would make these places very proper for observation. The difference between them at *Tobolsk* in *Siberia* and at *St. Helena* will be 11 minutes, according to DE L'ISLE's map: at *Archangel* it will be but about 40 seconds less than at *Tobolsk*; and only a minute and a quarter less at *Petersburgh*, even if the Sun's parallax be no more than $10''\frac{1}{2}$. At *Wardhus* the same advantage would nearly be gained as at *Tobolsk*: but if the observers could go still farther to the east, as to *Yakoutsk* in *Siberia*, the advantage would be still greater; for, as Mr. DE L'ISLE very justly observes, in a memoir presented to the *French* king with his map of the transit, the difference of time between Venus's egress from the Sun at *Yakoutsk* and at the *Cape of Good Hope* will be $13\frac{1}{2}$ minutes.

70. This method requires that the longitude of each place of observation be ascertained to the

greateſt degree of nicety, and that each obſerver's clock be exactly regulated to the equal time at his place: for without theſe particulars it would be impoſſible for the obſervers to reduce the times to thoſe which are reckoned under any given meridian; and without reducing the obſerved times of egreſs at different places to the time at ſome given place, the abſolute time that elapſeth between the egreſs at one place and at another could not be found. But the longitudes may be found, by obſerving the eclipſes of Jupiter's ſatellites; and a true meridian, for regulating the clock, to the time at any place, may be had, by obſerving when any given ſtar, within 20 or 30 degrees of the pole, is ſtationary, with regard to it's azimuth, on the eaſt and weſt ſides of the pole: the pole itſelf being the middle point between theſe two ſtationary poſitions of the ſtar. And it is not material for the obſervers to know exactly either the true angular meaſure of the Sun's diameter, or of Venus's, in this caſe; for whatever their diameters be, it will make no ſenſible difference in the obſerved interval between the ſame contact, as ſeen from different places.

71. In the geometrical conſtruction of tranſits, the ſcale *AB* (Fig. 3. of Plate XVI.) may be divided into any given number of equal parts, anſwering to any aſſumed quantity of Venus's horizontal parallax from the Sun (which is always the difference between the horizontal parallax of Venus and that of the Sun) provided the whole length of the ſcale be equal to the ſemidiameter of the Earth's diſc in Fig. 4.—Thus, if we ſuppoſe Venus's horizontal parallax from the Sun to be only 26″ (inſtead of 31″) in which caſe the Sun's horizontal parallax muſt be 10″.3493, as in § 20, the reſt of the projection will anſwer to that ſcale: as *CD*, which contains only 26 equal parts, is the ſame length as *AB*, which contains 31. And by working in all other reſpects as taught from § 45 to

§ 62,

§ 62, you will find the times of total ingreſs and beginning of egreſs; and conſequently, the duration of the tranſit at any given place, which muſt reſult from ſuch a parallax.

72. In projections of this kind, it may be eaſily conceived, that a right line paſſing continually through the center of Venus, and a given point of the Earth, and produced to the Sun's diſc, will mark the path of Venus on the Sun as ſeen from the given point of the Earth: and in this there are three caſes. 1. When the given point is the Earth's center, at which there is no parallax, either in longitude or latitude. 2. When the given point is one of the poles, where there is no parallax of longitude; but a parallax of latitude, whoſe quantity is eaſily determined, by letting fall a perpendicular from the pole upon the plane of Venus's orbit, and ſetting off the parallax of latitude on this perpendicular: and here, the polar tranſit-lines will be parallel to the central; as the poles have no motion ariſing from the Earth's diurnal rotation. 3. The laſt caſe is, when the given point of the Earth is any point of it's ſurface, whoſe latitude is leſs than 90 degrees: then there is a parallax in latitude proportional to the perpendicular let fall upon the aboveſaid plane, from the given point; and a parallax in longitude proportional to the perpendicular let fall upon the axis of that plane, from the ſaid given point. And the effect of this laſt will be to alter the tranſit-line, both in poſition and length; and will prevent it's being parallel to the central tranſit-line, unleſs when it's axis and the axis of the Earth coincide, as ſeen from the Sun; which is a thing that may not happen in many ages.

ARTICLE

ARTICLE VI.

Concerning the map of the transit. Plate XVII.

73. The title of this map, and the lines drawn upon it, together with the words annexed to these lines, and the numbers [hours and minutes] on the dotted lines, explain the whole of it so well, that no farther description seems requisite.

74. So far as I can examine the map by a good globe, the black curve lines are in general pretty well laid down, for shewing at what places the transit will begin, or end, at sun-rising or sun-setting, to all those places through which they are drawn, according to the times mentioned in the map. Only I question much whether the transit will begin at sun-rise to any place in *Africa*, that is west of the *Red-Sea*; and am pretty certain that the Sun will not be risen to the northmost part of *Madagascar* when the transit begins, as M. De L'Isle reckons the first contact of Venus with the Sun to be the beginning of the transit. So that the line which shews the entrance of Venus in the Sun's disc at sun-rising, seems to be a little too far west in the map, at all places which are south of *Asia Minor*: but in *Europe*, I think it is very well.

75. In delineating this map, I had M. De L'Isle's map of the transit before me. And the only difference between his map and this is, 1. That in his map, the times are computed to the meridian of *Paris*; in this they are reduced to the meridian of *London*. 2. I have changed his meridional projection into that of the equatorial; by which, I apprehend, that the black curve lines, shewing at what places the transit begins, or ends, with the rising or setting Sun, appear more natural to the eye, and are more fully seen at once, than in the map from which I copied: for, in that map, the lines are interrupted and broke in the meridian

A MAP of the EARTH, *Upon which are marked the Hours and Minutes of true Times of the Entrance and Exit of* VENUS, *in its Passage over the* SUN's DISC, June 6th 1761. *The Times are computed to the Meridian of* LONDON, *and that which is expressed upon each dotted Line shews when the Transit begins or ends at all those Places which the same Line passes through. The beginning is between* II *and* III *in the Morning and the end between* VIII *and* IX. *The four black curve Lines shew at what Places the Transit begins, and at what Places its ends, both at Sun rising and Sun setting.*

J. Ferguson delin.   J. Mynde sculp.

that divides the hemiſpheres; and the places where they ſhould join cannot be perceived ſo readily by thoſe who are not well ſkilled in the nature of ſtereographical projections.—The like may be ſaid of many of the dotted curve lines, on which are expreſſed the hours and minutes of the beginning or ending of the tranſit, which are the abſolute times at theſe places through which the lines are drawn, computed to the meridian of *London*.

ARTICLE VII.

Containing an Account of Mr. HORROX's *Obſervation of the Tranſit of Venus over the Sun, in the Year* 1639; *as it is publiſhed in the* Annual Regiſter *for the Year* 1761.

76. When *Kepler* firſt conſtructed his (the Rudolphine) Tables upon the obſervations of *Tycho*, he ſoon became ſenſible that the Planets Mercury and Venus would ſometimes paſs over the Sun's diſc; and he predicted two tranſits of Venus, one for the year 1631, and the other for 1761, in a tract publiſhed at *Leipſick* in 1629, entitled, *Admonitio ad Aſtronomos, &c.* *Kepler* died ſome days before the tranſit in 1631, which he had predicted was to have happened. *Gaſſendi* looked for it at *Paris*, but in vain (ſee *Mercurius in Sole viſus, & Venus inviſa.)* In effect, the imperfect ſtate of the Rudolphine Tables was the cauſe that the tranſit was expected in 1631, when none could be obſerved; and thoſe very tables did not give reaſon to expect one in 1639, when one was really obſerved.

When our illuſtrious countryman Mr. HORROX firſt applied himſelf to Aſtronomy, he computed Ephemerides for ſeveral years, from *Lanſbergius*'s Tables. After continuing his labours for ſome time, he was enabled to diſcover the imperfection of theſe tables; upon which he laid aſide his work, intending

intending to determine the poſitions of the ſtars from his own obſervations. But that the former part of his time ſpent in calculating from *Lanſbergius* might not be thrown away, he made uſe of his Ephemerides to point out to him the ſituations of the planets. From hence he foreſaw when their conjunctions, their appulſes to be fixed ſtars, and the moſt remarkable phenomena in the heavens would happen; and prepared himſelf with the greateſt care to obſerve them.

Hence he was encouraged to wait for the important obſervation of the tranſit of Venus in the year 1639; and no longer thought the former part of his time miſpent, ſince his attention to *Lanſbergius*'s Tables had enabled him to diſcover that the tranſit would certainly happen on the 24th of *November*. However, as theſe tables had ſo often deceived him, he was unwilling to rely on them entirely, but conſulted other tables, and particularly thoſe of *Kepler*; accordingly, in a letter to his friend *William Crabtree* of *Mancheſter*, dated *Hool*, *October* 26, 1639, he communicated his diſcovery to him, and earneſtly deſired him to make whatever obſervation he poſſibly could with his teleſcope, particularly to meaſure the diameter of the planet Venus; which, according to *Kepler*, would amount to 7 minutes of a degree, and according to *Lanſbergius* to 11 minutes; but which, according to his own proportion, he expected it would hardly exceed one minute. He adds, that according to *Kepler*, the conjunction will be *November* 24, 1639, at 8 hours 1 minute A. M. at *Mancheſter*, and that the planet's latitude would be 14′ 10″ ſouth; but according to his own corrections, he expected it to happen at 3 hours 57 min. P. M. at *Mancheſter*, with 10′ ſouth latitude. But becauſe a ſmall alteration in *Kepler*'s numbers would greatly alter the time of conjunction, and the quantity of the planet's latitude, he adviſes to watch the whole day, and even on the preceding afternoon, and the morning

of

of the 25th, though he was entirely of opinion that the tranſit would happen on the 24th.

After having fully weighed and examined the ſeveral methods of obſerving this uncommon phenomenon, he determined to tranſmit the Sun's image through a teleſcope into a dark chamber, rather than through a naked aperture, a method greatly commended by *Kepler*; for the Sun's image is not given ſufficiently large and diſtinct by the latter, unleſs at a very great diſtance from the aperture, which the narrowneſs of his ſituation would not allow of; nor would Venus's diameter be well defined, unleſs the aperture were very ſmall; whereas his teleſcope, which rendered the ſolar ſpots diſtinctly viſible, would ſhew him Venus's diameter well defined, and enable him to divide the Sun's limb more accurately.

He deſcribed a circle on paper which nearly equalled ſix inches, the narrowneſs of the place not allowing a larger ſize; but even this ſize admitted diviſions ſufficiently accurate. He divided the circumference into 360 degrees, and the diameter into 30 equal parts, each of which were ſubdivided into 4, and the whole therefore into 120. The ſubdiviſion might have ſtill been carried farther, but he truſted rather to the accuracy and niceneſs of his eye.

When the time of obſervation drew near, he adjuſted the apparatus, and cauſed the Sun's diſtinct image exactly to fill the circle on the paper; and though he could not expect the planet to enter upon the Sun's diſc before three o'clock in the afternoon of the 24th, from his own corrected numbers, upon which he chiefly relied; yet, becauſe the calculations in general from other tables gave the time of conjunction much ſooner, and ſome even on the 23d, he obſerved the Sun from the time of it's riſing to nine o'clock; and again, a little before ten; at noon, and at one in the afternoon: being called in the intervals to buſineſs of the

the higheſt moment, which he could not neglect. But in all theſe times he ſaw nothing on the Sun's face, except one ſmall ſpot, which he had ſeen on the preceding day; and which alſo he afterward ſaw on ſome of the following days.

But at 3 hours 15 minutes in the afternoon, which was the firſt opportunity he had of repeating his obſervations, the clouds were entirely diſperſed, and invited him to ſeize this favourable occaſion, which ſeemed to be providentially thrown in his way; for he then beheld the moſt agreeable ſight, a ſpot, which had been the object of his moſt ſanguine wiſhes, of an unuſual ſize, and of a perfectly circular ſhape, juſt wholly entered upon the Sun's diſc on the left ſide; ſo that the limbs of the Sun and Venus perfectly coincided in the very point of contact. He was immediately ſenſible that this ſpot was the planet Venus, and applied himſelf with the utmoſt care to proſecute his obſervations.

And, *Firſt*, with regard to the inclination, he found, by means of a diameter of the circle ſet perpendicular to the horizon, the plane of the circle being ſomewhat reclined on account of the Sun's altitude, that Venus had wholly entered upon the Sun's diſc, at 3 hours 15 minutes, at about 62° 30′ (certainly between 60° and 65°) from the vertex toward the right hand. (Theſe were the appearances within the dark chamber, where the Sun's image and motion of the planet thereon were both inverted and reverſed.) And this inclination continued conſtant, at leaſt to all ſenſe, till he had finiſhed the whole of his obſervation.

Secondly, The diſtances obſerved afterward between the centers of the Sun and Venus were as follows. At 3 hours 15 minutes by the clock, the diſtance was 14′ 24″; at 3 hours 35 minutes, the diſtance was 13′ 30″; at 3 hours 45 minutes, the diſtance was 13′ 0″. The apparent time of ſunſetting was at 3 hours 50 minutes—the true time

3 hours

3 hours 45 minutes—refraction keeping the Sun above the horizon for the ſpace of 5 minutes.

Thirdly, He found Venus's diameter, by repeated obſervations, to exceed a thirtieth part of the Sun's diameter, by a ſixth, or at moſt a fifth ſubdiviſion. —The diameter therefore of the Sun to that of Venus may be expreſſed, as 30 to 1.12. It certainly did not amount to 1.30, nor yet to 1.20. And this was found, by obſerving Venus as well when near the Sun's limb, as when farther removed from it.

The place where this obſervation was made, was an obſcure village called *Hool*, about 15 miles miles northward of *Liverpool*. The latitude of *Liverpool* had been often determined by *Horrox* to be 53° 20′; and therefore, that of *Hool* will be 53° 35′. The longitude of both ſeemed to him to be about 22° 30′ from the *Fortunate Iſlands*; that is 14° 15′ to the weſt of *Uraniburg*.

Theſe were all the obſervations which the ſhortneſs of the time allowed him to make upon this moſt remarkable and uncommon ſight; all that could be done however in ſo ſmall a ſpace of time, he very happily executed; and ſcarce any thing farther remained for him to deſire. In regard to the inclination alone, he could not obtain the utmoſt exactneſs; for it was extremely difficult, from the Sun's rapid motion, to obſerve it to any certainty within the degree. And he ingeniouſly confeſſes that he neither did, nor could poſſibly perform it. The reſt are very much to be depended upon; and as exact as he could wiſh.

Mr. *Crabtree*, at *Mancheſter*, whom Mr. *Horrox* had deſired to obſerve this tranſit, and who in mathematical knowledge was inferior to few, very readily complied with his friend's requeſt; but the ſky was very unfavourable to him, and he had only one ſight of Venus on the Sun's diſc, which was about 3 hours 35 minutes by the clock; the Sun then, for the firſt time, breaking out from the clouds;

clouds; at which time, he ſketched out Venus's ſituation upon paper, which *Horrox* found to coincide with his own obſervations.

Mr. *Horrox*, in his treatiſe on this ſubject, publiſhed by *Hevelius*, and from which almoſt the whole of this account has been collected, hopes for pardon from the aſtronomical world, for not making his intelligence more publick; but his diſcovery was made too late. He is deſirous however, in the ſpirit of a true philoſopher, that other aſtronomers were happy enough to obſerve it, who might either confirm or correct his obſervations. But ſuch confidence was repoſed in the tables at that time, that it does not appear that this tranſit of Venus was obſerved by any beſides our two ingenious countrymen, who proſecuted their aſtronomical ſtudies with ſuch eagerneſs and preciſion, that they muſt very ſoon have brought their favourite ſcience to a degree of perfection unknown at thoſe times. But unfortunately Mr. *Horrox* died on the 3d of *January* 1640-1, about the age of 25, juſt after he had put the laſt hand to his treatiſe, entitled, *Venus in Sole viſa*, in which he ſhews himſelf to have had a more accurate knowledge of the dimenſions of the Solar Syſtem than his learned commentator *Hevelius*.——*So far the Annual Regiſter*.

In the year 1691 *, Dr. HALLEY gave in a paper upon the tranſit of Venus (See *Lowthorpe*'s Abridgement of the Philoſophical Tranſactions, pag. 434.) in which he obſerves, from the tables then in uſe, that Venus returns to a conjunction with the Sun in her aſcending node in a period of 18 years, wanting 2 days 10 hours $52\frac{1}{2}$ minutes; but that in the ſecond conjunction ſhe will have got 24′ 41″ farther to the ſouth than in the preceding. That after a period of 235 years 2 hours 10 minutes 9 ſeconds, ſhe returns to a conjunction more to the north by 11′ 33″; and after 243 years, wanting 43

* See the *Connoiſſance des Temps* for *A. D.* 1761.

minutes, in a point more to the ſouth by 13′ 8″. But if the ſecond conjunction is in the year next after leap year, it will be a day later.

The intervals of the conjunctions at the deſcending node are ſomewhat different. The ſecond happens in a period of 8 years, wanting 2 days 6 hours 55 minutes, Venus being got more to the north by 19′ 58″. After 235 years 2 days 8 hours 18 minutes, ſhe is 9′ 21″ more ſoutherly: only, if the firſt year is a biſſextile, a day muſt be added. And after 243 years 0 days 1 hour 23 minutes, the conjunction happens 10′ 37″ more to the north; and a day later, if the firſt year was biſſextile. It is ſuppoſed, as in the old ſtile, that all the centurial years are biſſextiles.

Hence, Dr. HALLEY finds the years in which a tranſit may happen at the aſcending node, in the month of *November* (old ſtile) to be theſe—918, 1161, 1396, 1631, 1639, 1874, 2109, 2117: and the tranſits in the month of *May* (old ſtile) at the deſcending node, to be in theſe years—1048, 1283, 1518, 1526, 1761, 1769, 1996, 2004.

In the firſt caſe, Dr. HALLEY makes the viſible inclination of Venus's orbit to be 9° 5′, and her horary motion on the Sun 4′ 7″. In the latter, he finds her viſible inclination to be 8′ 28″, and her horary motion 4′ 0″. In either caſe, the greateſt poſſible duration of a tranſit is 7 hours 56 minutes.

Dr. HALLEY could even then conclude, that if the interval in time between the two interior contacts of Venus with the Sun could be meaſured to the exactneſs of a ſecond, in two places properly ſituated, the Sun's parallax might be determined within it's 500dth part.—But ſeveral years after, he explained this concluſion more fully, in a paper concerning the tranſit of Venus in the year 1761; which was publiſhed in the Philoſophical Tranſactions, and of which the third of the preceding articles is a tranſlation; the original having been wrote in *Latin* by the Doctor.

ARTICLE VIII.

Containing a short account of some observations of the Transit of Venus, A. D. 1761, June 6*th*, *New Stile*; *and the distances of the planets from the Sun, as deduced from those observations.*

Early in the morning, when every astronomer was prepared for observing the transit, it unluckily happened, that both at *London*, and the Royal Observatory at *Greenwich*, the sky was so overcast with clouds, as to render it doubtful whether any part of the transit should be seen:—and it was 38 minutes 21 seconds past 7 o'clock (apparent time) at *Greenwich*, when the Rev. Dr. *Bliss*, our Astronomer Royal, first saw Venus on the Sun; at which instant, the center of Venus preceded the Sun's center by 6′ 18″.9 of right ascension, and was south of the Sun's center by 18′ 42″.1 of declination.—From that time to the beginning of egress the Doctor made several observations, both of the difference of right ascension and declination of the centers of the Sun and Venus; and at last found the beginning of egress, or instant of the internal contact of Venus with the Sun's limb, to be at 8 hours 19 minutes 0 seconds apparent time.—From the Doctor's own observations, and those which were made at *Shirburn* by another gentleman, he has computed, that the mean time at *Greenwich* of the ecliptical conjunction of the Sun and Venus was at 51 minutes 20 seconds after 5 o'clock in the morning; that the place of the Sun and Venus was ♊ (*Gemini*) 15° 36′ 33″; and that the geocentric latitude of Venus was 9′ 44″.9 south.—her horary motion from the Sun 3′ 57″.13 retrograde.—and the angle then formed by the axis of the equator, and the axis of the ecliptic, was 6° 9′ 34″, decreasing hourly 1 minute of a degree.—By the mean of three good observations, the diameter of Venus on the Sun was 58″.

Mr. *Short* made his obſervation at *Savile-Houſe*, in *London*, 30 ſeconds in time weſt from *Greenwich*, in preſence of his royal highneſs the duke of *York*, accompanied by their royal highneſſes prince *William*, prince *Henry*, and prince *Frederick*.—He firſt ſaw Venus on the Sun, through flying-clouds, at 46 minutes 37 ſeconds after 5 o'clock; and at 6 hours 15 minutes 12 ſeconds he meaſured the diameter of Venus 59″.8.—He afterward found it to be 58″.9 when the ſky was more favourable.—And, through a reflecting teleſcope of two feet focus, magnifying 140 times, he found the internal contact of Venus with the Sun's limb to be at 8 hours 18 minutes 21½ ſeconds, apparent time; which, being reduced to the apparent time at *Greenwich*, was 8 hours 18 minutes 51½ ſeconds: ſo that his time of ſeeing the contact was 8½ ſeconds ſooner (in abſolute time) than the inſtant of it's being ſeen at *Greenwich*.

Meſſrs. *Ellicott* and *Dollond* obſerved the internal contact at *Hackney*, and their time of ſeeing it, reduced to the time at *Greenwich*, was at 8 hours 18 minutes 56 ſeconds, which was 4 ſeconds ſooner in abſolute time than the contact was ſeen at *Greenwich*.

Mr. *Canton*, in *Spittle-Square*, *London*, 4′ 11″ weſt of *Greenwich*, (equal to 16 ſeconds 44 thirds of time) meaſured the Sun's diameter 31′ 33″ 24‴, and the diameter of Venus on the Sun 58″; and by obſervation found the apparent time of the internal contact of Venus with the Sun's limb to be at 8 hours 18 minutes 41 ſeconds; which, by reduction, was only 2¼ ſeconds ſhort of the time at the Royal Obſervatory at *Greenwich*.

The Reverend Mr. *Richard Haydon*, at *Leſkeard*, in *Cornwall* (16 minutes 10 ſeconds in time weſt from *London*, as ſtated by Dr. *Bevis*) obſerved the internal contact to be at 8 hours 0 minutes 20 ſeconds, which by reduction was 8 hours 16 minutes 30 ſeconds at *Greenwich*: ſo that he muſt have ſeen it 2 minutes 30 seconds sooner in absolute time than it was seen at *Greenwich*—a difference by much too great to be occasioned by the difference of parallaxes. But by a memorandum of Mr. *Haydon*'s some years before, it appears that he then supposed his west longitude to be near two minutes more; which brings his time to agree within half a minute of the time at *Greenwich*; to which the parallaxes will very nearly answer.

At *Stockholm* Observatory, latitude 59° 20′$\frac{1}{2}$ north, and longitude 1 hour 12 minutes east from *Greenwich*, the whole of the transit was visible: the total ingress was observed by Mr. *Wargentin* to be at 3 hours 39 minutes 23 seconds in the morning, and the beginning of egress at 9 hours 30 minutes 8 seconds: so that the whole duration between the two internal contacts, as seen at that place, was 5 hours 50 minutes 45 seconds.

At *Torneo* in *Lapland* (1 hour 27 minutes 28 seconds east of *Paris*) Mr. *Hellant*, who is esteemed a very good observer, found the total ingress to be at 4 hours 3 minutes 59 seconds; and the beginning of egress to be 9 hours 54 minutes 8 seconds. —So that the whole duration between the two internal contacts was 5 hours 50 minutes 9 seconds.

At *Hernosand*, in *Sweden* (latitude 6° 38′ north, and longitude 1 hour 2 minutes 12 seconds east of *Paris*) Mr. *Gister* observed the total ingress to be at 3 hours 38 minutes 26 seconds; and the beginning of egress to be at 9 hours 29 minutes 21 seconds.—The duration between these two internal contacts 5 hours 50 minutes 56 seconds.

Mr. *De la Lande*, at *Paris*, observed the beginning of egress to be at 8 hours 28 minutes 26 seconds apparent time.—But Mr. *Ferner* (who was then at *Conflans*, 14″$\frac{1}{2}$ west of the Royal Observatory at *Paris*) observed the beginning of egress to be at 8 hours 28 minutes 29 seconds true time. The equation, or difference between the true and apparent

apparent time, was 1 minute 54 ſeconds.—The total ingreſs, being before the Sun roſe, could not be ſeen.

At *Tobolſk*, in *Siberia*, Mr. *Chappe* obſerved the total ingreſs to be at 7 hours 0 minutes 28 ſeconds in the morning, and the beginning of egreſs to be at 49 minutes $20\frac{1}{2}$ ſeconds after 12 at noon.—So that the whole duration of the tranſit between the internal contacts was 5 hours 48 minutes $52\frac{1}{2}$ ſeconds, as ſeen at that place: which was 2 minutes $3\frac{1}{2}$ ſeconds leſs than as ſeen at *Hernoſand* in *Sweden*.

At *Madraſs*, the Reverend Mr. *Hirſt* obſerved the total ingreſs to be at 7 hours 47 minutes 55 ſeconds apparent time in the morning; and the beginning of egreſs at 1 hour 39 minutes 38 ſeconds paſt noon.—The duration between theſe two internal contacts was 5 hours 51 minutes 43 ſeconds.

Profeſſor *Mathenci* at *Bologna* obſerved the beginning of egreſs to be at 9 hours 4 minutes 58 ſeconds.

At *Calcutta* (latitude 22° 30′ north, nearly 92° eaſt longitude from *London*) Mr. *William Magee* obſerved the total ingreſs to be at 8 hours 20 minutes 58 ſeconds in the morning, and the beginning of egreſs to be at 2 hours 11 minutes 34 ſeconds in the afternoon. The duration between the two internal contacts 5 hours 50 minutes 36 ſeconds.

At the *Cape of Good Hope* (1 hour 13 minutes 35 ſeconds eaſt from *Greenwich*) Mr. *Maſon* obſerved the beginning of egreſs to be at 9 hours 39 minutes 50 ſeconds in the morning.

All theſe times are collected from the obſervers' accounts, printed in the Philoſophical Tranſactions for the years 1762 and 1763, in which there are ſeveral other accounts that I have not tranſcribed.—The inſtants of Venus's total exit from the Sun are likewiſe mentioned, but they are here left out, as not of any uſe for finding the Sun's parallax.

Whoever compares theſe times of the internal contacts, as given in by different obſervers, will find ſuch difference among them, even thoſe which were taken upon the ſame ſpot, as will ſhew, that the inſtant of either contact could not be ſo accurately perceived by the obſervers as Dr. HALLEY thought it could: which probably ariſes from the difference of peoples eyes, and the different magnifying powers of thoſe teleſcopes through which the contacts were ſeen.—If all the obſervers had made uſe of equal magnifying powers, there can be no doubt but that the times would have more nearly coincided: ſince it is plain, that ſuppoſing all their eyes to be equally quick and good, they whoſe teleſcopes magnified moſt, would perceive the point of internal contact ſooneſt, and of the total exit lateſt.

Mr. *Short* has taken an incredible deal of pains in deducing the quantity of the Sun's parallax, from the beſt of thoſe obſervations which were made both in *Britain* and abroad: and finds it to have been 8″.52 on the day of the tranſit, when the Sun was very nearly at his greateſt diſtance from the Earth; and conſequently 8″.65 when the Sun is at his mean diſtance from the Earth.—And indeed, it would be very well worth every curious perſon's while, to purchaſe the ſecond part of Volume LII of the Philoſophical Tranſactions, for the year 1763; even if it contained nothing more than Mr. *Short*'s paper on that ſubject.

The log. ſine (or tangent) of 8″.65 is 5.6219140, which being ſubtracted from the radius 10.0000000, leaves remaining the logarithm 4.3780860, whoſe number is 23882.84; which is the number of ſemidiameters of the Earth that the Sun is diſtant from it.—And this laſt number, 23882.84, being multiplied by 3985, the number of *Engliſh* miles contained in the Earth's ſemidiameter, gives 95,173,117 miles for the Earth's mean diſtance from the Sun.—But becauſe it is impoſſible, from the niceſt obſervations of the Sun's parallax, to be ſure of its true diſtance from the Earth within 100 miles,

miles, we ſhall at preſent, for the ſake of round numbers, ſtate the Earth's mean diſtance from the Sun at 95,173,000 *Engliſh* miles.

And then, from the numbers and analogies in § 11 and 14 of this Diſſertation, we find the mean diſtances of all the reſt of the planets from the Sun in miles to be as follows.—Mercury's diſtance, 36,841,468; Venus's diſtance, 68,891,486; Mars's diſtance, 145,014,148; Jupiter's diſtance, 494,990,976; and Saturn's diſtance, 907,956,130 *.

So that, by comparing theſe diſtances with thoſe in the Tables at the end of the chapter on the Solar Syſtem †, it will be found that the dimenſions of the Syſtem are much greater than what was formerly imagined; and conſequently, that the Sun and all the planets (except the Earth) are much larger than as ſtated in that table.

The ſemidiameter of the Earth's annual orbit being equal to the Earth's mean diſtance from the Sun, viz. 95,173,000 miles, the whole diameter thereof is 190,346,000 miles. And ſince the circumference of a circle is to it's diameter as 355 is to 113, the circumference of the Earth's orbit is 597,989,646 miles.

And, as the Earth deſcribes this orbit in 365 days 6 hours (or in 8766 hours) it is plain that it travels at the rate of 68,216.9 miles every hour, and conſequently 1136.9 miles every minute; ſo that it's velocity in it's orbit is at leaſt 142 times as great as the velocity of a cannon-ball, ſuppoſing the ball to move through 8 miles in a minute, which it is found to do very nearly:—and at this rate it would take 22 years 228 days for a cannon-ball to go from the Earth to the Sun.

* When I computed the diſtances in the laſt line of § 174, pag. 106. I had heard that the Sun's parallax was found to be 8″ 69; which occaſions the difference between thoſe diſtances and theſe which ariſe here from the parallax 8″.65, as I found it in the Philoſophical Tranſactions.

† Fronting pag. 40.

On the 3d of *June*, in the year 1769, Venus will again paſs over the Sun's diſc, in ſuch a manner, as to afford a much eaſier and better method of inveſtigating the Sun's parallax than her tranſit in the year 1761 has done.—But no part of *Britain* will be proper for obſerving that tranſit, ſo as to deduce any thing with reſpect to the Sun's parallax from it, becauſe it will begin but a little before ſun-ſet, and will be quite over before 2 o'clock next morning.—The apparent time of conjunction of the Sun and Venus, according to Dr. HALLEY's Tables, will be at 13 minutes paſt 10 o'clock at night at *London*; at which time, the geocentric latitude of Venus will be full 10 minutes of a degree north from the Sun's center:—and therefore, as ſeen from the northern parts of the Earth, Venus will be conſiderably depreſſed by a parallax of latitude on the Sun's diſc; on which account, the viſible duration of the tranſit will be lengthened: and in the ſouthern parts of the Earth ſhe will be elevated by a parallax of latitude on the Sun, which will ſhorten the viſible duration of the tranſit, with reſpect to it's duration as ſuppoſed to be ſeen from the Earth's center; to both which affections of duration the parallaxes of longitude will alſo conſpire.—So that every advantage which Dr. HALLEY expected from the late tranſit will be found in this, without the leaſt difficulty or embarraſſment.—It is therefore to be hoped, that neither coſt nor labour will be ſpared in duly obſerving this tranſit; eſpecially as there will not be ſuch another opportunity again in leſs than 105 years afterward.

The moſt proper places for obſerving the tranſit in the year 1769 is in the northern parts of *Lapland*, and the *Solomon Iſles* in the great *South-Sea*; at the former of which, the viſible duration between the two internal contacts will be at leaſt 22 minutes greater than at the latter, even though the

Sun's

Sun's parallax ſhould not be quite 9″——If it be 9″ (which is the quantity I had aſſumed in a delineation of this tranſit, which I gave in to the Royal Society before I had heard what Mr. *Short* had made it from the obſervations on the late tranſit) the difference of the viſible durations, as ſeen in *Lapland* and in the *Solomon Iſles*, will be as expreſſed in that delineation; and if the Sun's parallax be leſs than 9″ (as I now have very good reaſon to believe it is) the difference of durations will be leſs accordingly.

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Sun's parallax should not be quite 9″.——If it be 9″ (which is the quantity I had assumed in a delineation of this transit, which I gave in to the Royal Society before I had heard what Mr. Short had made it from the observations on the spot) the difference of the visible durations, as seen in England and in the Southern Sea, will be as expressed in that delineation; and if the Sun's parallax be less than 9″ (as I now have very good reason to believe it is) the difference of durations will be less accordingly.

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